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THE DEVELOPMENT AND HOMOLOGIES OF THE MOUTH PARTS OF INSECTS.

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THE problem of the homologies of the mouth parts of insects is one long worked at by zoölogists. Since Savigny's first statement in 1816 of his conclusions regarding the homologies of the arthropod appendages, this problem has been a favorite one with insect morphologists, and in this century of work much has been accomplished. There is a practically complete agreement as to the homologies of the parts of the biting mouth as this mouth is variously composed in the Orthoptera, Coleoptera, Neuroptera, *et al.*, and a fair agreement obtains with regard to the interpretation of the homologies of some of the more modified kinds of mouth parts possessed by the piercing and sucking insects. This is true especially of those insects, like the Hymenoptera and the Lepidoptera, among which there are generalized forms showing the essential biting type (as with the sawflies among the Hymenoptera and Eriocephala and Micropteryx among the Lepidoptera), together with a series of gradatory forms leading plainly up to the highly specialized conditions exhibited by the higher members of these orders.

These homology-determinations were first made by a study of the comparative anatomy of the fully developed mouth parts (those of adult insects), and indeed have a fairly safe grounding on this comparative anatomical study alone. But with the development of embryological studies of insects came the confirmation of these determinations, or some of them, by the study of the development of the mouth parts. From their origin as budding appendages, arising on the successive segments of the embryonic head, their development has been readily and certainly traced to the definitive mouth-part condition ; and mandibles, maxillæ, and labium are as certainly serially homologous with each other and with the legs and antennæ as are the more obviously homologous segmental appendages of the crustaceans.

But this ontogenic development of the insectean mouth parts, simple and continuous as it is in the case of insects with an incomplete metamorphosis, is a very complex and difficult subject of study in all of those insects which undergo what is termed a complete metamorphosis, and this for the reason, now familiar to entomologists, that in the late larval and early pupal life of such insects a more or less radical histolysis, or breaking down of the larval organs and tissues, occurs, with a building up of the imaginal organs from small, primitive centers called histoblasts (imaginal disks), which are not derived from the corresponding larval organs but (for the appendages as legs and mouth parts) from the larval derm or cellular skin layer. Thus we have in the development of the mouth parts of insects with complete metamorphosis a discontinuity which sadly interferes with the determination of homologies by ontogenetic study. Indeed, so serious has this obstacle proved that we have as yet practically no complete tracing through both embryonic and post-embryonic development of the growth and development of the mouth parts of any insect of complete metamorphosis. And they are, for the most part, precisely those insects of most radical post-embryonic metamorphosis which possess in adult condition the most highly modified and specialized mouth parts, and which present to us the most serious task in the interpretation of the mouth-part homologies. The Diptera, of course, best exemplify these conditions.

There is no special difficulty, outside of the general difficulties which the study of insect embryology commonly presents, in tracing from beginning up to completed larval condition the development of the mouth parts of insects with complete metamorphosis; and the homologies of these larval mouth parts with the mouth parts of adult insects with incomplete metamorphosis can accordingly be determined on a basis of ontogenic study (also, of course, on a basis of comparative anatomy). The biting mouth parts of the more generalized flies, of the lepidopterous caterpillars and coleopterous grubs, can be homologized with the mandibles, maxillæ, and labium of the adult cockroaches and locusts, constituting the generalized biting or so-called orthopterous mouth. But when the attempt is made to carry the homologies on to the adult piercing and sucking mouths of the flies and butterflies we lose in the prepupal stage our grip on the continuity of embryonic and adult mouth conditions and find ourselves forced to rest our interpretation of the homologies of the adult dipterous, lepidopterous, and hymenopterous mouth on the basis of comparative anatomical studies. And fortunately for us the persistence of certain generalized forms already referred to enables us to make a pretty secure determination of these homologies for all of the orders except the Diptera. To my mind, indeed, the study of the comparative anatomy of the mouth parts of the generalized flies (families of the Nematocera) enables us to be pretty certain even in that order, but such an attempt[1] of mine in 1899 has certainly failed to be convincing to several entomologists.

There is necessary, then, the completion of the tracing of the development of the mouth parts; nothing less, under the circumstances that the most generalized of dipterous mouths are not at all generalized (if one may be so paradoxical), but are so specialized that no safe determination of the homologies can be made on the basis of comparative anatomy, — nothing less will be convincing or satisfactory for the solid grounding of an interpretation of the homologies of the mouth parts of

[1] The Mouth Parts of the Nematocerous Diptera, *Psyche*, vol. viii (1899): I, pp. 303–306, January; II, pp. 327–330, March; III, pp. 346–348, April; IV, pp. 355–359, May; V, pp. 363–365, June; with 11 figs.

the Diptera, and if this tracing can be effected for the other orders of holometabolous insects, it will put the homology-determinations on a much better foundation than they now have. It is the beginnings of such an attempt that is outlined in this paper.

Neuroptera.

The Neuroptera belong to the holometabolous insects, *i.e.*, insects with complete metamorphosis, but this metamorphosis in many forms is of a very simple and straightforward kind as compared with the radical metamorphosis of a fly or butterfly, for example. The mouth parts of the adult insect are, too, of the orthopterous or biting type, and there is no question regarding the interpretation of the mouth-part homologies. Mandibles, maxillæ, and labium of the neuropterous mouth are obviously homologous with the similarly named parts of the orthopterous mouth. Furthermore, the differences between the larval and adult mouth parts are comparatively slight, and no question is made regarding the homologies between the two sets. Yet it is worth while to trace the development of the imaginal parts in its more conspicuous features, and get a first sight at the relation between larval and imaginal mouth parts in a holometabolous insect. This relation is readily made out in the large and familiar neuropteron called the "dobson fly," or "hellgrammite," *Corydalis cornuta*.

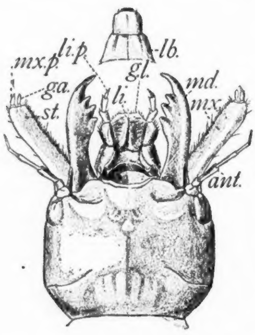


Fig. 1.—Dorsal aspect of head of larva of *Corydalis cornuta*, with labrum removed. *lb.*, labrum; *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *st.*, stipes; *ga.*, galea; *li.*, labium; *li.p.*, labial palpus; *ant.*, antenna.

Corydalis cornuta (Figs. 1–5).—The mouth parts of the larval Corydalis are shown in Fig. 1, and their orthopterous character, together with the details of the various parts, are so readily apparent that little description is needed. The mandibles (*md.*) are very heavy and long; the maxillæ (*mx.*) have a short proximal segment, cardo (not visible in the drawing),

and a usually elongate parallel-sided stipes (*st.*) bearing at its terminal extremity the much-reduced three-segmented palpus (*mx.p.*) and a still smaller two-segmented terminal lobe, or galea (*ga.*), the lacinia being wholly wanting; the labium (*li.*) has the glossæ (*gl.*) (inner terminal lobes) fused but emarginate, the paraglossæ (outer terminal lobes) wanting, and the palpi (*li.p.*) three-segmented and well developed. The mouth parts are similar in both sexes.

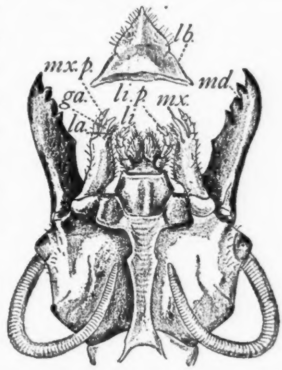


FIG. 2.—Ventral aspect of head of pupa of *Corydalis cornuta*. *lb.*, labrum; *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *ga.*, galea; *la.*, lacinia; *li.*, labium; *li.p.*, labial palpus.

When the larval dobson is ready to pupate (at the probable age of three years) it leaves the stream it has lived in, crawls under some stone near the water's edge, and changes into a quiet, non-feeding pupa, which, however, is not enclosed in a hard, opaque cuticle, but retains the power of violent wriggling, and bears the wing pads and legs only loosely appressed to the body. The mouth parts of the pupa (Fig. 2) show slight yet obvious differences from those of the larva (and also from those of the imago). The mandibles (*md.*) show a difference from the larval mandibles in the character of the dentation and in outline of the whole sclerite; the maxillæ have short, five-segmented palpi and two short terminal lobes, *i.e.*, both galea (*ga.*) and lacinia (*lc.*), and the labium (*li.*) has its free margin more emarginate and less truncate or blunt, the palpi (*li.p.*) remaining three-segmented.

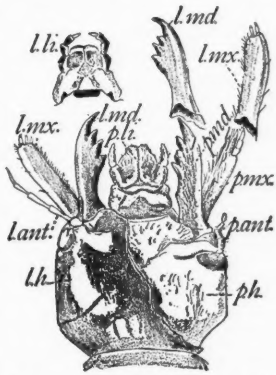


FIG. 3.—Dorsal aspect of head of old larva of *Corydalis cornuta*, with body wall of right side (in figure) dissected away, showing pupal head beneath. *l.h.*, larval head wall; *l.md.*, larval mandible; *l.mx.*, larval maxilla; *l.li.*, larval labium; *l.ant.*, larval antenna; *p.h.*, wall of pupal head; *p.md.*, pupal mandible; *p.mx.*, pupal maxilla; *p.li.*, pupal labium; *p.ant.*, pupal antenna.

If one dissects away the cuticle of the head of an old larva about to pupate, the pupal mouth parts will be found formed fairly within the old larval ones, and thus in perfect correspondence with them. Rather it would be truer to say that they are apparently the transformed larval parts minus the to-be-shed larval cuticle. This is shown in Fig. 3, in which the larval cuticle of the right-hand half of the head (including the whole of the labium) has been dissected away, exposing the

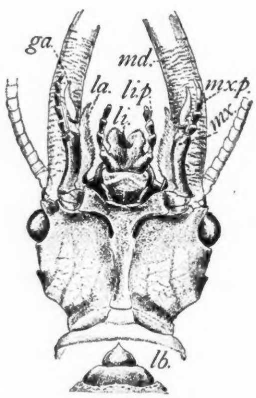


Fig. 4.

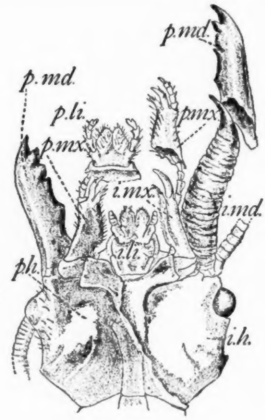


Fig. 5.

Fig. 4.—Ventral aspect of head of adult male *Corydalis cornuta*. *lb.*, labrum; *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *ga.*, galea; *la.*, lacinia; *li.*, labium; *li.p.*, labial palpus.

Fig. 5.—Ventral aspect of head of pupa of *Corydalis cornuta*, the pupal body wall being dissected away on right side (in figure), showing forming imaginal head and appendages. *p.md.*, pupal mandible; *p.mx.*, pupal maxilla; *p.li.*, pupal labium; *p.h.*, pupal body wall of head; *i.md.*, imaginal mandible; *i.mx.*, imaginal maxilla; *i.li.*, imaginal labium; *i.h.*, body wall of imaginal head.

still soft, unchitinized pupal cuticle, while the left side of the head is still wholly larval. From the right pupal mandible has been slipped the larval mandibular sheath, from the right pupal maxilla has been slipped the larval maxillar sheath, and from the whole pupal labium has been removed the larval covering. But the slight changes in outline and character of the pupal mouth parts are plainly apparent, while the identity of larval and pupal mandibles, maxillæ, and labium is unmistakable. There is yet no apparent difference in the mouth parts of the sexes.

In the adult (Fig. 4) we find mouth parts still of simple orthopterous type, with parts plainly homologous with the various orthopterous parts, and also as plainly with the parts of its own larva and pupa; but in the male the familiar but extraordinary modification of the mandibles, converting them from biting and masticating organs into a pair of long, non-dentate, pointed, clasping organs (*md.*) for holding the female, attracts our special attention. But these organs are certainly mandibles; the maxillæ (*mx.*) and labium (*li.*), changed slightly to be still more thoroughly orthopterous in type, are in their own places, and no other mandibulate organs except the claspers are present. In the female the imaginal mandibles are of usual biting dentate type. To make sure of the mandibulate character of the long claspers we have but to dissect the head of an old pupa, as shown in Fig. 5. In this figure the pupal cuticle has been removed from the right-hand half of the head, while left intact on the left side. Removing the pupal labial cuticle, the imaginal labium, practically identical with the pupal one, is exposed, with the palpi shortened by "telescoping" but ready to expand to full length; within the pupal maxillar sheath the imaginal maxilla in its now thoroughly orthopterous character is found, and within the comparatively short, strongly dentate, pupal mandible is found,

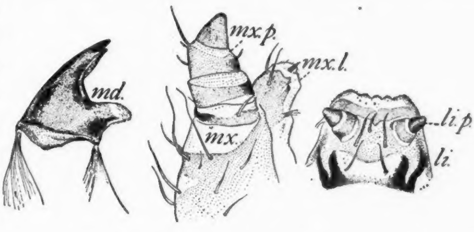


Fig. 6.—Mouth parts of larva of *Anatis 15-punctata*. *md.*, mandible; *mx.*, maxilla; *mx.l.*, maxillar lobe; *mx.p.*, maxillary palpus; *li.*, labium; *li.p.*, labial palpus.

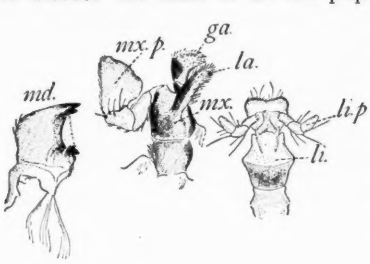


Fig. 7.—Mouth parts of adult *Anatis 15-punctata*. *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *ga.*, galea; *la.*, lacinia; *li.*, labium; *li.p.*, labial palpus.

strongly "telescoped," the strange adult mandible, with its lack of dentation, its pointed tip, and its great length (easily attained by extension of the longitudinally compressed organ as discovered within the pupal sheath). Thus the transformation of larval parts into pupal, and of pupal into imaginal, is obvious, and the homologies between larval and imaginal parts are firmly founded on ontogenic basis.

COLEOPTERA.

The Coleoptera, like the Neuroptera, have biting mouth parts in both larval and imaginal stages, but the differences are usually greater, and the general metamorphosis is on the whole more radical.

Anatis 15-punctata (Figs. 6–8). — The accompanying figures made from a study of the mouth parts of *Anatis 15-punctata* illustrate the relations between larval and imaginal mouth parts of a member of the order. The larvæ (Fig. 6) have strongly chitinized, sharp-toothed mandibles (*md.*), maxillæ (*mx.*) with single terminal lobe (*mx.l.*), rather large four-segmented palpus (*mx.p.*), and fleshy liplike labium (*li.*), with fused terminal lobes and short one-segmented palpus (*li.p.*) inserted on a segment-like projection. In the adult (Fig. 7) the mandibles (*md.*) are shorter and heavier, the maxillæ (*mx.*) have both terminal lobes, galea (*ga.*) and lacinia (*lc.*), distinct, and four-segmented palpi (*mx.p.*), the distal segment being much broader than the others. The labium (*li.*) is rather elongate, with distinct basal sclerites (submentum and mentum), fused terminal lobes, and short three-segmented palpi (*li.p.*).

The small size of the larval head precludes such dissections as were easily made in the case of Corydalis, and the thickness and opacity of the chitinized cuticle of the head makes it impossible to clear specimens and study the forming imaginal head within, a method very successfully used in the cases of the honeybee and digger wasp (see *postea*). The development of the imaginal head and mouth parts had to be studied by means of sections, and here again the firmness of the head wall offered a serious obstacle to satisfactory work. I have

been able, however, to get series showing plainly the later steps of the development of the imaginal parts within the head of old larvæ. The developing imaginal parts, their definitive outlines already so strongly indicated as to make them recognizable (apart from their position), lie within the corresponding parts of the larval head (Fig. 8), imaginal mandibles with their tips within the larval mandibles, imaginal maxillæ with their two terminal lobes lying partly within and corresponding to the single terminal lobe of the larva, and imaginal palpi lying almost wholly within the larval palpi, and finally imaginal labium lying in the base of the larval labium. All of the forming imaginal parts are plainly seen to be folds or evaginations of the forming imaginal derm layer, which shows in sections as a continuous broad cellular line lying just underneath the larval integument.

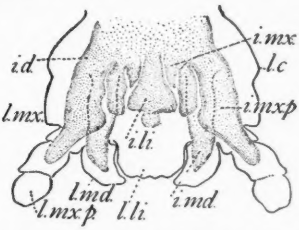


FIG. 8. — Semi-diagrammatic drawing of anterior portion of frontal horizontal section through the head of old larva of *Anatis 15-punctata* showing pupal (= imaginal) mouth parts forming underneath the larval integument. *l.c.*, larval cuticle; *i.d.*, imaginal derm; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *l.mx.p.*, larval maxillary palpus; *i.mx.*, imaginal maxilla; *i.mx.p.*, imaginal maxillary palpus; *l.li.*, larval labium; *i.li.*, imaginal labium.

Thus in Anatis we have practically the same conditions of development of the imaginal mouth parts within, and corresponding to, the larval mouth parts as we found in Corydalis.

LEPIDOPTERA.

Among the Lepidoptera we find a great range in degree of specialization of the mouth parts. In Eriocephala and Micropteryx, as described by Walter[1] and myself,[2] the mouth parts are really of the biting type, the mandibles being short, heavy, and dentate, true jaws, the maxillæ showing a cardo, stipes, short galea, and lacinia, and long six-segmented palpus, and the labium being liplike, with plainly distinguishable submentum

[1] Walter, A. Beiträge zur Morphologie der Schmetterlinge, *Jenaische Zeitschr. f. Naturwiss.*, vol. xviii (1885), pp. 751–807.

[2] Kellogg, V. L. The Mouth Parts of the Lepidoptera, *Amer. Nat.*, vol. v (1895), pp. 546–556, Pl. XXV.

and mentum and prominent three-segmented palpi. But in all the Lepidoptera above the Eriocephalidæ, Micropterygidæ, and Tineidæ, from a considerable to a very pronounced specialization is present, manifested by a complete reduction of the mandibles, by the reduction of the labium to a small rigid plate on the ventral side of the mouth bearing the persisting three-segmented palpi, and by a remarkable modification of the maxillæ whereby the galeæ (or laciniæ) are prolonged, grooved on their inner surfaces, and apposed to form the familiar sucking proboscis, while the other parts of the maxillæ are reduced and fused to form a rigid supporting base for the proboscis. In numerous moths no food is taken in the adult condition, and here the proboscis itself is reduced slightly or much, even to complete atrophy, and in extreme cases there is no mouth opening at all.

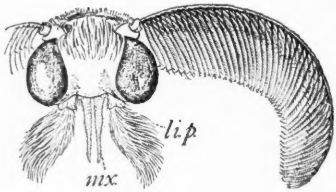


FIG. 9.—Frontal aspect of head of imago of *Notolophus leucostigma*. *mx.*, maxilla; *li.p.*, labial palpus.

Notolophus leucostigma (Figs. 9–12). — In the white-marked tussock moth, *Notolophus leucostigma*, the mouth parts (Fig. 9) of the adult, although functionless, or at least apparently incapable of taking food, show all the usual parts peculiar to the typical specialized lepidopterous mouth. The labium is a small fixed plate, forming part of the ventral wall of the head and bearing the conspicuous hairy three-segmented palpi (*li.p.*); the maxillæ (*mx.*) are simply two slender tapering processes, the halves of the usual proboscis, but in this case not applied to each other and hence not forming a sucking tube ; the maxillary palpi are wholly reduced, and the mandibles entirely wanting.

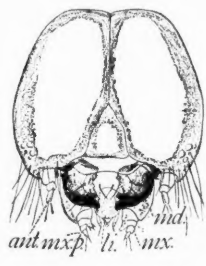


FIG. 10. — Frontal aspect of head of larva of *Notolophus leucostigma*. *ant.*, antenna ; *md.*, mandible ; *mx.*, maxilla ; *mx.p.*, maxillary palpus ; *li.*, labium.

In the caterpillar (Fig. 10) the biting mouth parts common to lepidopterous larvæ are present, with full complement of

distinct and readily recognizable mandibles (*md.*), maxillæ (*mx.*) with short but distinct three-segmented palpi (*mx.p.*), and labium (*li.*) with very small ex-articulate palpi.

If an old larva, nearly ready to pupate, be taken, and its head dissected, as illustrated in Fig. 11, it will be found that underneath, or within, the larval labium, or labial cuticle, will be found the forming imaginal labial palpi; within the larval maxilla will be found the forming imaginal maxillæ, while within the larval mandible will be found nothing at all. In Fig. 11 the larval cuticle of the left side of the head has been dissected away, showing this correspondence between larval and imaginal parts; the larval maxillary sheath has been slipped off of the forming imaginal maxillar process, while on that part of the forming imaginal head from which the larval mandible was taken there is not a trace even of a forming organ. Fig. 12 shows the entirely dissected-out pupal (equals subimaginal head), with the already unmistakably recognizable imaginal mouth parts.

Fig. 11. — Frontal aspect of head of old larva of *Notolophus leucostigma*, with body wall of left side (in figure) dissected away, showing pupal (= imaginal) head underneath. *l.ant.*, larval antenna; *l.md.*, larval mandible; *l.mx.*, larval maxilla; *l.li.*, larval labium; *lb.*, larval labrum; *ant.*, imaginal antenna; *i.mx.*, imaginal maxilla.

Fig. 12. — Pupal (= imaginal) head of *Notolophus leucostigma* dissected out of larval head. *mx.*, maxilla; *li.p.*, labial palpus; *ant.*, antenna.

Thus in this representative of the Lepidoptera we find the imaginal mouth parts developing in perfect correspondence with the larval parts, imaginal maxillæ within larval maxillæ, imaginal labium in larval labium, and within the well-developed larval mandibles *nothing*, with a corresponding total absence of mandibles in the fully developed moth. By sectioning the heads of old larvæ, it is readily perceivable that these developing imaginal mouth parts lying within and corresponding to the various larval parts are evaginations of the new or imaginal derm which forms a continuous layer underneath the

larval integument. Similarly, it is apparent that the imaginal antennæ and compound eyes are in the one case evaginations and in the other simply modified portions of this imaginal derm; and although I have not made cuttings of a complete series of heads from young to oldest larvæ, enough of the younger stages have been studied to show the simple dermal origin of all these parts by a continuous process of evagination and modification. We are sufficiently acquainted with the origin and mode of development of the legs and wings of insects from histoblasts to recognize in these histoblasts, or developmental centers, simple invaginations of the derm, which later become evaginations. Whether an organ, as wing, leg, antenna, or mouth part, shall begin as an invagination or an evagination of the derm is chiefly a matter of mechanical necessity or ease, and of degree of radicalness in the metamorphosis. In either case the ultimate origin, that of being simply a particular portion or area of derm, is the same; the invagination must become an evagination; the difference lies in the mechanical factors of the developmental process.

Hymenoptera.

In the order Hymenoptera there is to be found, as in the Lepidoptera, a wide range of degree of specialization of the mouth parts, varying from the biting, orthopterous mouth of the sawflies to the highly modified sucking mouth of the honey-bee; but throughout the order the mandibles persist in plainly jawlike character, and are always recognizable landmarks in mouth-part dissections. The only questions in the homology-interpretation occur in those cases where the labium and maxillæ are much modified and more or less completely fused or bound together. But these questions are not very serious; entomologists are fairly agreed, on a basis of comparative anatomical study, on the interpretation of the homologies of the hymenopterous mouth parts. But the results of a study of the post-embryonic development of the mouth parts, *i.e.*, the development of the imaginal mouth parts, undertaken by one of my students, Mr. M. H. Spaulding, illuminate too beautifully

and effectively the whole study of the development of imaginal mouth parts in holometabolous insects to be overlooked because of the lack of any crying need for an ontogenic confirmation of the hymenopterous homologies. Mr. Spaulding has been admirably successful in so clearing and staining the heads of variously aged larvæ of the honeybee and of a digger wasp, Ammophila *sp.*, that the developing imaginal head within the larval integument may be as easily studied as the exterior of the larval head itself. The bee and wasp larvæ, it will be recalled, are both "inside feeders," *i.e.*, lie during their life enclosed in a protecting cell, in one case of wax, in the other of hardened mud, and thus may and do dispense with the heavily chitinized opaque head cuticle common to exposed insect larvæ. And both larvæ have full complements of mouth parts, namely, mandibles, maxillæ, and labium, — a condition not common to all larvæ in those two orders, Hymenoptera and Diptera, in which the post-embryonic metamorphosis is most radical. This condition is a necessary one for the determination of the relations of the imaginal to the larval parts.

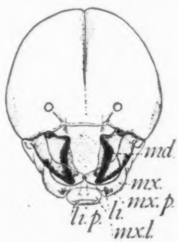


FIG. 13. — Frontal aspect of head of larva of digger wasp, *Ammophila* sp. *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *mx.l.*, maxillary lobe; *li.*, labium; *li.p.*, labial palpus.

Ammophila sp. (Figs. 13–15). — The larval mouth parts (Fig. 13) consist of well chitinized crushing mandibles (*md.*), short fleshy maxillæ (*mx.*) with very small one-segmented palpus (*mx.p.*) and smaller terminal lobe (*mx.l.*), and short liplike labium (*li.*) with pair of very small one-segmented palpi (*li.p.*). The adult wasp also has a complete complement of mouth parts (Fig. 14), all very elongate and slender, the mandibles (*md.*) heavily chitinized and toothed, the maxillæ (*mx.*) long and slender with distinct cardo and stipes, five-segmented palpus (*mx.p.*), and simple terminal lobe composed of the fused galea and lacinia, and the labium (*li.*) also long and narrow with fused submentum and mentum, four-segmented palpi (*li.p.*), slender ligula formed of the fused glossæ (*gl.*), and distinct slender paraglossæ (*p.g.*) less than half as long as the fused glossæ.

It is obvious that these long slender imaginal mouth parts cannot be contained within the very much shorter and altogether smaller larval parts. As a matter of fact, the whole imaginal head is for simple mechanical reasons forced to lie during its development chiefly in the anterior larval thoracic segment, the anterior portions, including the antennæ and mouth parts, projecting forward into the larval head capsule. But still there is indicated perfectly the correspondence between particular imaginal parts and particular larval parts

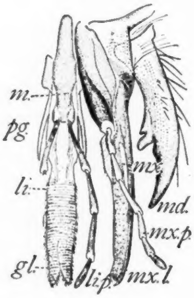


FIG. 14.

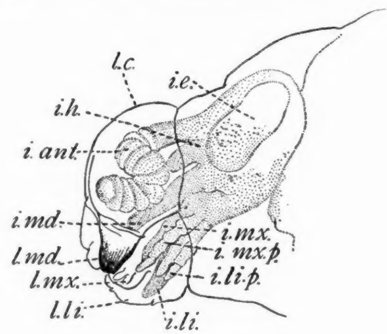


FIG. 15.

FIG. 14. — Mouth parts of adult digger wasp, *Ammophila* sp. (mandible, maxilla, and labial palpus of left side, in figure, not drawn). *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *mx.l.*, maxillary lobe; *li.*, labium; *li.p.*, labial palpus; *gl.*, glossæ; *pg.*, paraglossa; *m.*, mentum.

FIG. 15. — Head of old larva of digger wasp, *Ammophila* sp., cleared to show forming imaginal head within. *l.c.*, larval head wall; *i.h.*, forming imaginal head; *i.e.*, imaginal eye; *i.ant.*, imaginal antenna; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.*, imaginal maxilla; *i.mx.p.*, imaginal maxillary palpus; *l.li.*, larval labium; *i.li.*, imaginal labium; *i.li.p.*, imaginal labial palpus.

by the fact that the projecting tips of the elongate imaginal parts penetrate or lie within the short larval parts. This is shown clearly in the cleared and stained heads prepared by Mr. Spaulding, as well as in series of sections. Fig. 15 is drawn with camera lucida from one of the whole head preparations, and, as indicated by the lettering, those parts of the imago which we have, on the basis of comparative anatomy, assumed to compose the labium, do project into and correspond with the larval labium; the case is similar with maxillæ and mandibles. But, in origin, these imaginal mouth parts arise as

dermal modifications and outgrowths which for simple demands of space become far removed from the larval mouth parts, the bases of the developing imaginal parts lying, indeed, in late larval life in the first thoracic larval segment. But in earlier larval life the beginning imaginal parts lie almost wholly within the larval parts, and no one studying the series of whole head preparations and of sections can fail to be convinced of the certain correspondence and homology between larval and imaginal parts, although there may be said to be no perfect transformation or development of the one into the other, the evidence being that of a correspondence in position on the head and of part for part.

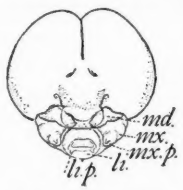


FIG. 16. — Frontal aspect of head of larva of honeybee, *Apis mellifica*. *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *li.*, labium; *li.p.*, labial palpus.

Apis mellifica (Figs. 16–18). — The beautiful series of cleared and stained heads of honeybee larvæ of different ages, and the series of sections of similar heads prepared by Mr. Spaulding, show a condition in the development of the imaginal mouth parts of the bee wholly identical with that just shown for the digger wasp. The larval mouth parts (Fig. 16) are very weakly chitinized, but are complete and readily distinguishable. They resemble in general the mouth parts of the digger wasp larva, but are smaller, weaker, and the short fleshy maxilla bears only the minute one-segmented palpus, having no tiny lobe as in the wasp maxilla. The imaginal mouth parts (Fig. 17) of the bee, familiar to all entomologists, are composed of horny, trowel-like mandibles (*md.*), long maxillæ (*mx.*) with cardo (*cd.*), stipes (*st.*), small one-segmented palpus (*mx.p.*), and with galea and lacinia fused to form a single flattened, pointed, bladelike terminal lobe (*mx.l.*), and of labium (*li.*) with long, tapering subcylindrical ligula formed

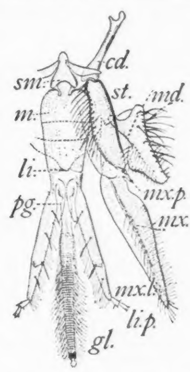


FIG. 17. — Mouth parts of adult honeybee, *Apis mellifica*. *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *mx.l.*, maxillary lobe; *st.*, stipes; *cd.*, cardo; *li.*, labium; *s.m.*, submentum; *m.*, mentum; *pg.*, paraglossa; *gl.*, glossa; *li.p.*, labial palpus.

of the fused glossæ (*gl.*), short but distinct flaplike paraglossæ (*pg.*), three-segmented palpi (*li.p.*) borne on a long palpiger, and at the base a distinct mentum (*m.*) and submentum (*sm.*).

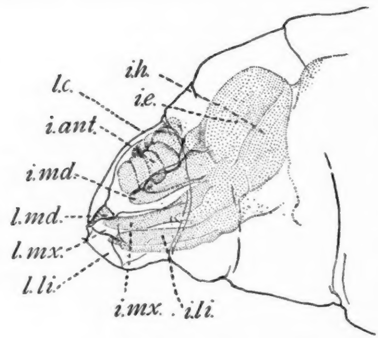


FIG. 18. — Head of old larva of honeybee, *Apis mellifica*, cleared to show forming imaginal head within. *l.c.*, larval head wall; *i.h.*, imaginal head; *i.e.*, imaginal eye; *i.ant.*, imaginal antenna; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.*, imaginal maxilla; *l.li.*, larval labium; *i.li.*, imaginal labium.

As with the digger wasp, the developing head of the imago, with its long antennæ and mouth parts, demands more space than is afforded within the larval head segment, so that it is crowded backward and occupies part of the first and second larval thoracic segments. But the forming imaginal mouth parts are to be found with their tips projecting into the corresponding larval parts, as shown in Fig. 18. The conditions of the development of the imaginal parts, and of their perfect correspondence with the larval parts, are wholly like those already explained for the digger wasp.

DIPTERA.

In the case of the Diptera, — and it is here that the necessity of ontogenetic study is most important, indispensable indeed, for the determination of the homologies, — we have, as in the Hymenoptera and Lepidoptera, a great variety of mouth-part conditions culminating in the extreme specialization characteristic of the muscid forms. In most Diptera it is obvious that a total reduction of at least one pair of the buccal appendages has occurred, with a large reduction and complete modification of the remaining parts. From a considerable study of the anatomy of the fully developed mouth parts in a long series of dipterous forms, including representatives of all except one (the Ornephilidæ) of the nematocerous families, —

those families by common agreement held to constitute the more generalized portion of the order, — I came to the conclusion that the old and most widely, if perhaps uncritically, accepted interpretation of the homologies of the dipterous one is the true one. This interpretation homologizes the labella-bearing proboscis common to all the more specialized flies with the labium of other insects, finds the maxillæ represented in these specialized forms chiefly or only by a pair of palpi, and finds the mandibles wholly wanting in all but the females of a few families. In the case of most of the nematocerous families the labium retains a truly labiumlike character and has not developed the pseudotracheæ-bearing labella, while the maxillæ are represented by a well-developed bladelike terminal lobe as well as by the palpi. The mandibles when present are of the character of elongate blades or stylets, never of the character of true crushing or biting jaws. The structural character of the mouth in each of the nematocerous families is described and illustrated in my series of papers (1899) in *Psyche*, previously referred to.

But several interpretations of the homologies of the mouth parts widely at variance with the above have been offered. In these various interpretations the possession of mandibles by any flies at all is denied; the so-called labium is considered to be composed of modified parts of the maxillæ, and the so-called maxillæ are believed to be parts of the labium; in fact, most of the possible changes which an active speculation could invent have been rung on the theme. Nor are these interpretations based on mere speculation; they are the results, in several cases, of prolonged and disinterested examination of considerable series of specimens.

In the face of such differences of opinion, and with the apparent limits of the method of the comparative study of the fully developed mouth parts of various members of the order reached, it becomes imperative to seek the clue to these lost homologies in the facts of development. And this is really the first object of this present study. Can the homologies of the dipterous mouth parts be discovered by the study of the development of the parts?

For a complete developmental study of the mouth parts of any dipteron it would be necessary to begin with the budding appendages of the head segments in early embryonic life, to trace the development of these appendages to their definitive form in the hatched larva, and finally to follow the transformation, if it occurs, of these larval parts into the ultimate imaginal ones. As a matter of fact, such actual transformation does not occur, so that the study of the postembryonic development of the mouth parts consists of noting the ecdysis of the larval parts and determining the ontogenic relations of the new imaginal parts to the old larval ones.

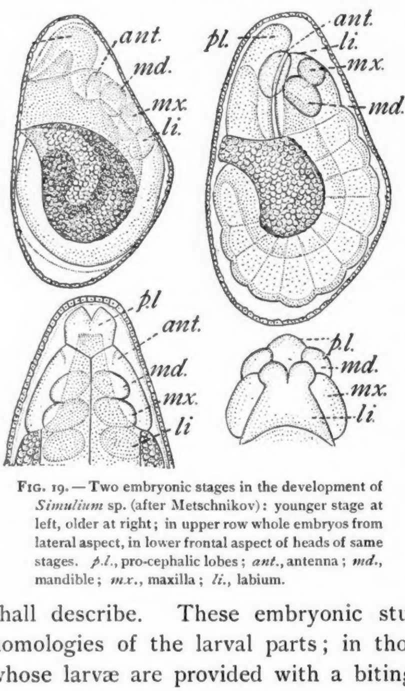


FIG. 19. — Two embryonic stages in the development of *Simulium* sp. (after Metschnikov): younger stage at left, older at right; in upper row whole embryos from lateral aspect, in lower frontal aspect of heads of same stages. *p.l.*, pro-cephalic lobes; *ant.*, antenna; *md.*, mandible; *mx.*, maxilla; *li.*, labium.

As for the embryonic development of the mouth parts, — *i.e.*, the development from budding appendages to definitive larval parts, — that has been done for several Diptera, and in particular by Metschnikov for Simulium, one of the two flies whose postembryonic development I shall describe. These embryonic studies make certain the homologies of the larval parts; in those flies like Simulium, whose larvæ are provided with a biting mouth with full complement of parts, it is easy to note plainly the development of mandibles, maxillæ, and labium from the successive pairs of budding head appendages (Fig. 19), and thus to homologize these parts certainly with the mandibles, maxillæ, and labium of adult insects of incomplete metamorphosis. There remains to determine the relations of the larval mouth parts of Simulium with its very different imaginal mouth parts.

In selecting flies for the study of the postembryonic development of the mouth parts I have chosen two which in the imaginal condition possess all the parts possessed by any fly, and these parts in as generalized condition as is to be found in the order, and which also possess in the larval stage a similarly full complement of mouth parts. Such larvæ as those of the Muscidæ, with their problematical hooks and lack of other parts, and such imagines as the muscid flies, with no parts left except proboscis and maxillary palpi, are impossible for the determination of the relation between larval and imaginal parts. From the mouth parts of the imaginal Simulium and of other nematocerous forms it is not difficult to trace the evolution to the specialized muscid conditions, and if the mouth parts of Simulium and similarly equipped flies can be interpreted, the various members of the dipterous series culminating in the muscids can. So in Simulium and Blepharocera I have found suitable forms for study; both with females possessing the so-called mandibles, both with maxillæ and labium well developed in both sexes, and both with larvæ equipped with biting mouths with unmistakable mandibles, maxillæ, and labia, and in one case, that of Simulium, with the embryonic development of the larval mouth parts fully traced and the homologies certainly[1] determined.

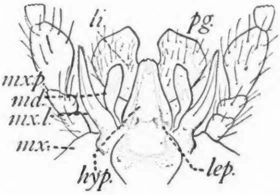


FIG. 20. — Mouth parts of adult *Simulium* sp., female. *l.ep.*, labrum-epipharynx; *hyp.*, hypopharynx; *md.*, mandible; *mx.*, maxilla; *mx.l.*, maxillary lobe; *mx.p.*, maxillary palpus; *li.*, labium; *pg.*, paraglossa.

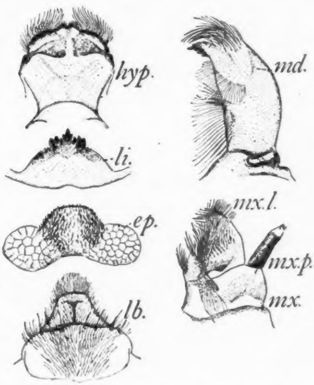


FIG. 21. — Mouth parts of larva of *Simulium* sp. *md.*, mandible; *mx.*, maxilla; *mx.l.*, maxillary lobe; *mx.p.*, maxillary palpus; *lb.*, labrum; *ep.*, epipharynx; *li.*, labium; *hyp.*, hypopharynx.

[1] Metschnikov, E. Embryologische Studien an Insekten, *Zeitschr. f. wiss. Zool.*,

Simulium sp. (Figs. 20–23). — In the female imago[1] the mouth parts (Fig. 20) consist of a short liplike labium (*li.*) composed of a short basal sclerite and three terminal lobes, being the two large paraglossæ (*pg.*) and a median short membranous lobe, the fused glossæ; of a pair of maxillæ (*mx.*), each consisting of a basal sclerite, a long five-segmented palpus (*mx.p.*), and a single pointed, bladelike terminal lobe (*mx.l.*) reaching nearly to the end of the third palpar segment, serrate on its inner margin at the tip and better developed than in most Nematocera; and of a pair of short mandibles (*md.*), broad, thin, and weakly chitinized. As in other nematocerous flies, there is a well-developed labrum-epipharynx (*l.ep.*) and an elongate flattened hypopharynx (*hyp.*). In the males the mandibles are wanting.

In the larva (Fig. 21) the mouth is of the biting type, with short-toothed and heavy mandibles (*md.*), short, jawlike maxilla (*mx.*) with distinct one-segmented palpus (*mx.p.*), and a small, strongly chitinized labium (*li.*) or labial plate. In addition, labrum (*lb.*), epipharynx (*ep.*), and hypopharynx (*hyp.*) are all well developed.

The head of the larva having a thoroughly opaque, strongly chitinized cuticle, it was impossible to clear whole heads sufficiently to make visible the developing imaginal head and its parts, so that the method of sections had to be relied on to reveal the internal conditions. These sections of heads of larvæ of various ages show plainly that the general method of development of the imaginal parts within the larval head, and the correspondence between forming imaginal parts and the corresponding larval parts already noted in the other orders of holometabolous insects, hold good in the Diptera. Fig. 22 shows in sagittal longitudinal section the forming imaginal head parts within the larval head. This section shows particularly well the relation of the forming imaginal antenna to the

vol. xvi, 1866; embryonic development of mouth parts of Simulium described on pp. 392–421.

[1] In describing the adult mouth I shall assign to the various parts those names which, from my earlier study of the comparative anatomy, seem correctly used, and the use of which is confirmed by the results of this ontogenetic study.

larval antenna. In the larva the antennæ are very small compared with their size in the imago, and the imaginal antenna is thus forced, in its development, to occupy a region in the larval head not included in the larval antenna. But the tip of the imaginal organ lies fairly within the larval organ, thus indicating by correspondence in position, what is plainly obvious from anatomical consideration, the homology between the larval and imaginal organs. Similarly the forming imaginal mouth parts are to be found in unmistakable correspondence or homologous relation with the larval parts. By tracing the development of the parts, marked in Fig. 22 as the forming

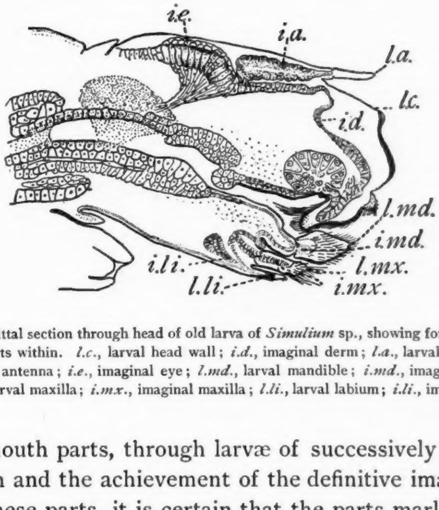


FIG. 22. — Sagittal section through head of old larva of *Simulium* sp., showing forming imaginal head parts within. *l.c.*, larval head wall; *i.d.*, imaginal derm; *l.a.*, larval antenna; *i.a.*, imaginal antenna; *i.e.*, imaginal eye; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.*, imaginal maxilla; *l.li.*, larval labium; *i.li.*, imaginal labium.

imaginal mouth parts, through larvæ of successively older ages to pupation and the achievement of the definitive imaginal condition of these parts, it is certain that the parts marked respectively imaginal mandible, imaginal maxillæ, and imaginal labium, lying respectively in the larval mandibles, maxillæ, and labium (with homologies firmly based on ontogenic basis), do develop into those definitive imaginal parts named mandibles, maxillæ, and labium in Fig. 20, illustrating a dissection of the mouth parts in a female adult Simulium. Fig. 23, a horizontal, frontal section through the head of a Simulium larva, shows also the forming imaginal maxilla and mandibles within corresponding larval parts.

Bibiocephala doanei[1] Kellogg (Figs. 24–26). — The Blepharoceridæ, or net-winged midges, agree with the Simulidæ, or black flies, in having the females equipped with mandibles, which in the Blepharoceridæ are well developed as long, slender, bladelike saws (see Fig. 24, *md.*) used to lacerate the bodies (as I have observed) of the tiny midges caught as prey by the bloodthirsty females. In addition the adult females have maxillæ (Fig. 24, *mx.*) with well-developed lobe (*mx.l.*) and long five-segmented palpus (*mx.p.*), and a labium (*li.*) consisting of strong elongate basal sclerite which presents indications of a line of fusion of submentum and mentum, and a pair of free fleshy terminal lobes, the paraglossæ (*pg.*). The males are equipped like the females except for the mandibles.

The larva of *Bibiocephala doanei* has a biting mouth (Fig. 25) composed of short, stout, crushing mandibles (*md.*), weaker jawlike maxillæ (*mx.*) without palpi, and a soft liplike labium (*li.*). In addition there are well-developed labrum-epipharynx (*l.ep.*) and hypopharynx (*hyp.*).

The development of the imaginal head shows the same phenomena as in Simulium. In Fig. 26, from a vertical transverse section through the head of an old larva, the derm of the forming imaginal head is plainly seen in continuous layer, modified at *i.e.* to produce the developing compound eyes and at *mx.* and *md.* the forming imaginal mandibles and maxillæ. In this section the imaginal parts of the maxillæ visible are the forming palpi, and their definitive, long, segmented condition is plainly to be seen in these telescoped organs tucked tightly inside the larval maxillæ. The forming mandibles do not yet show their definitive character, but in tracing these organs through a series of older larvæ the gradual taking-on of the slender sawlike character is manifest. The series of Blepharocera preparations which I have show even more plainly than the Simulium preparations the perfect correspondence and "box-in-box" sort of relation which exists between the larval

[1] This blepharocerid fly was described by me in *Psyche*, vol. ix (April, 1900), pp. 39–41, 2 figs., under the name *Liponeura doanei*. In a recent revision of the North American Blepharoceridæ, now in press, I refer this species to the genus Bibiocephala.

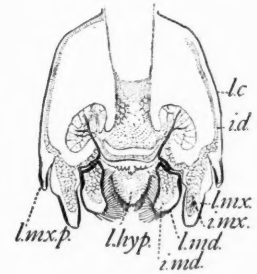


FIG. 23.

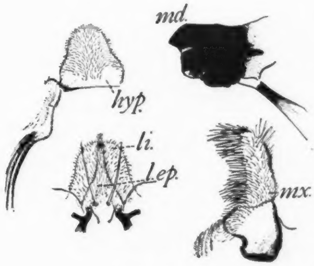


FIG. 25.

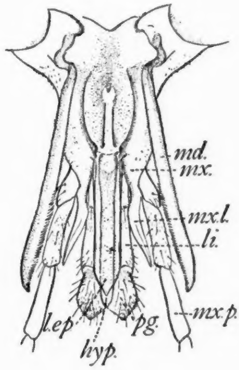


FIG. 24.

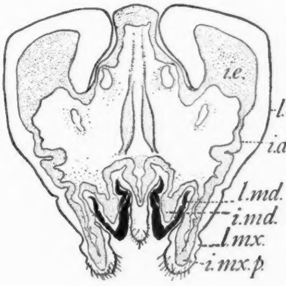


FIG. 26.

FIG. 23. — Frontal section, through the head of old larva of *Simulium* sp., showing forming imaginal parts. *l.c.*, larval cuticle; *i.d.*, imaginal derm; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.*, imaginal maxilla; *l.mx.p.*, larval maxillary palpus; *l.hyp.*, larval hypopharynx.

FIG. 24. — Mouth parts of adult *Bibiocephala doanei*, female; *md.*, mandible; *mx.*, maxilla; *mx.l.*, maxillary lobe; *mx.p.*, maxillary palpus; *li.*, labium; *pg.*, paraglossa; *l.ep.*, labrum-epipharynx; *hyp.*, hypopharynx.

FIG. 25. — Mouth parts of larva of *Bibiocephala doanei*. *md.*, mandible; *mx.*, maxilla; *li.*, labium; *l.ep.*, labrum-epipharynx; *hyp.*, hypopharynx.

FIG. 26. — Frontal section, through head of old larva of *Bibiocephala doanei*, showing forming imaginal head parts within. *l.c.*, larval head wall; *i.d.*, imaginal derm; *i.e.*, imaginal eye; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.p.*, imaginal maxillary palpus.

mouth parts, of whose homologies no doubt can exist, and the forming imaginal parts, of whose homologies, in definitive condition, I thought myself long ago able to speak confidently on a basis of comparative anatomical study, but of which now on a basis of ontogenetic study I am simply without doubt.

Stanford University, California.
January, 1902.

AN ANALYTICAL KEY TO THE GENERA OF THE FAMILY FORMICIDÆ, FOR THE IDENTIFICATION OF THE WORKERS.

CARLO EMERY.

(Translated by WILLIAM MORTON WHEELER.[1])

SINCE the publication by Mayr, in 1865, of the volume on the Formicidæ of the voyage of the *Novara*, no comprehensive work has appeared which could be of service in the identification of the genera of this family. The number of these genera has increased considerably in the mean time, and the definitions formerly given by Mayr for a number of them are no longer exact, as their characters have been modified by the discovery of new species. Moreover, certain genera have been subdivided, others fused together; and all of this is to be found scattered about in a host of detached publications, so that it is almost impossible for any one who is not a consummate specialist to find his way about in the labyrinth.

I originally began, for my own personal use, to construct analytical tables for the workers of the subfamilies Myrmicinæ and Ponerinæ; but I now believe that I would render a service to entomologists by publishing these tables, after having revised and completed them. I have added tables of the genera of the other subfamilies, together with a table of the characters of the subfamilies themselves, likewise in analytical form.

[1] For the present authorized translation Professor Emery has carefully revised the tables of the Myrmicinæ, Dolichoderinæ, and Camponotinæ, of his "Clef Analytique des Genres de la Famille des Formicides, pour la Determination des neutres" (*Ann. Soc. Entomol. Belgique*, tome xl (1896), pp. 172–189), and has, moreover, permitted me to translate the as yet unpublished German table for the Dorylinæ and Ponerinæ which he has been preparing for *Das Thierreich*. The work has thus been brought up to date and cannot fail to be of great service to myrmecologists the world over. — W. M. WHEELER.

I trust that these tables will facilitate the labor of identification and enable those who are beginning to study the exotic ants to find their way more easily. I am well aware of the fact that one may find one's self in doubt at certain bifurcations of the path. How is one to know, *e.g.*, whether the worker is dimorphic, when one has only a single specimen of the species? I have made no use of such characters except when I had nothing better to present, and then I have tried to reinforce them as much as possible with accessory characters. Sometimes I have cited characters peculiar to the males and females, as these are often the most important in distinguishing certain genera, the workers of which present only feeble or insignificant differences. Nevertheless, I decline to attempt for the present an analysis of the sexual forms, which are still too imperfectly known.

In the enumeration of the segments of the abdomen I include the one or two constituting the pedicel, so that the segment following this, and usually designated by other authors as the first abdominal, is for me the third in the Myrmicinæ, the second in the Camponotinæ, etc.; the last visible segment is, therefore, always the sixth in the females and workers, the seventh in the males. In the male I designate as "subgenital lamina" what is usually, but improperly, called the hypopygium and is in reality the ventral lamina of the eighth segment. For the anatomy of the gizzard and the poison apparatus I would refer the reader to the works of Forel, Dewitz, and myself.[1]

Having adopted the dichotomic form for the identification of the genera, it follows that the order cannot express their natural affinities; but this can lead to no inconvenience in a

[1] Forel, A. Études myrmécologiques en 1878. Anatomie du Gésier des Fourmis, *Bull. Soc. Vaudoise Sc. Nat.*, vol. xv (1878), pp. 339–362, Pl. XXIII; Der Giftapparat und die Analdruesen der Ameisen, *Zeitschr. f. wiss. Zool.*, Bd. xxx, Suppl. (1878), pp. 28–68, Taf. III–IV.

Dewitz, H. Ueber Bau und Entwickelung des Stachels der Ameisen, *Zeitschr. f. wiss. Zool.*, Bd. xxviii (1877), pp. 527–556, Taf. XXVI.

Emery, C. Ueber den sogenannten Kaumagen einiger Ameisen, *Zeitschr. f. wiss. Zool.*, Bd. xlvi (1888), pp. 378–412, Taf. XXVII–XXIX.

In the plates will be found figures of all the forms of the gizzard in the Dolichoderinæ.

work the aim of which is essentially practical. I have marked with an asterisk the names of the genera represented in the Palearctic fauna.[1]

Characters of the Subfamilies.

I. Cloacal orifice in the shape of a slit; sting well developed or rudimental.

§ Sting developed, though sometimes very small, but capable nevertheless of being exserted from the abdomen. The first two segments of the abdomen usually modified, either forming together a two-jointed pedicel, or the first alone (petiole) forming the pedicel, the second (postpetiole) being merely constricted posteriorly and articulating with a spheroidal surface of the third segment, which is usually transversely striated (stridulatory organ); rarely the second segment is not appreciably modified.

† Nymphs usually enveloped in a cocoon; pedicel consisting of a single segment, more rarely of two, but in this case the frontal carinæ are very close to each other and do not cover the insertions of the antennæ (Dorylinæ) or the mandibles are linear and denticulate (Myrmecia).

a. Frontal carinæ very close to each other, almost vertical, not at all covering the antennal insertions (except Acanthostichus); abdominal pedicel of one or two segments. In the male the genitalia are completely retractile and the subgenital lamina is usually (perhaps always) furcate; cerci absent
1st subfamily, Dorylinæ

b. Frontal carinæ separated or close together; in the latter case they are dilated anteriorly to form an oblique or horizontal lamina, covering in part the insertion of the antennæ; abdominal pedicel of a single segment (except Myrmecia); copulatory organs of the male incompletely retractile; subgenital lamina never furcate (except in Paraponera); cerci nearly always present . . 2d subfamily, Ponerinæ

†† Nymphs naked; pedicel of two segments; rarely the postpetiole is attached to the following segment over its whole extent. Frontal carinæ usually separated from each other. In the male the copulatory organs are almost always exserted (being entirely retractile only in certain genera of the group Solenopsidii); cerci nearly always present (except Anergates)
3d subfamily, Myrmicinæ

[1] In addition, I have indicated by heavy type, in the translation, the names of all genera known to be represented in the ant fauna of the United States.—W. M. Wheeler.

§§ Sting rudimentary (except Aneuretus); abdominal pedicel consisting of a single segment; no constriction between the second and third segments of the abdomen; the poison glands are often rudimental and there are anal glands which secrete an aromatic product of characteristic odor (Tapinoma-odor). Nymphs without a cocoon 4th subfamily, DOLICHODERINÆ

II. Cloacal orifice round, terminal, surrounded by a fringe of hairs; sting transformed into a sustentacular apparatus for the orifice of the poison vesicle, which has a peculiar structure — called by Forel "pulviniferous vesicle" (*vessie à coussinet*). Abdominal pedicel consisting of a single segment; no constriction between the second and third segments. Nymphs rarely naked, most frequently enclosed in a cocoon. Male genitalia not retractile 5th subfamily, CAMPONOTINÆ

1st and 2d Subfamilies: DORYLINÆ *and* PONERINÆ.

1. Eyes large, three ocelli, mandibles slender, denticulate; postpetiole campanulate, narrower than the succeeding segment (Australian) Myrmecia Fab.
   Of a different conformation 2
2. Antennæ 6-jointed; first joint of hind tarsi dilated (African) Melissotarsus Emery
   Antennæ with more than six joints; tarsi simple 3
3. Postpetiole hardly wider than the petiole, and much narrower than the anterior border of the following segment, and on this account appearing as the second segment of the abdomen 4
   Postpetiole of a different conformation 6
4. Antennæ 12-jointed (neotropical) . . . . **Eciton** Latr.
   Antennæ 9–10-jointed 5
5. Hind legs without spurs, funiculus not club-shaped (Asia, Africa, Australia) . . . . Ænictus Shuckard
   Hind legs with spurs; last antennal joint separated off as a club (Asia, Australia) . . . . Cerapachys F. Smith (Subgenera Oöceræa and Cysias)
6. Postpetiole shorter than the following segment and somewhat narrower, but not distinctly separated from the latter; mesoëpinotal suture obsolete, promesonotal suture distinct; pygidium 3-pointed; antennæ 7–12-jointed; no eyes (Asia, Africa) . . . . . Dorylus Fabr.
   Postpetiole as in the preceding; mesoëpinotal suture distinct, promesonotal suture obsolete; antennæ 12-jointed (neotropical) Cheliomyrmex Mayr
   Of a different conformation 7
7. The frontal carinæ, which are fused with each other and with the clypeus, form a plate projecting out over the mandibles; the antennæ are inserted close to the anterior margin of this structure . . . 8

Frontal carinæ of a different conformation 9

8. Antennæ 12-jointed; abdomen stretched out straight (Africa)
Probolomyrmex Mayr

Antennæ 9-jointed, tip of the abdomen deflected down and forward (America, Africa, Australia) . . . . . . Discothyrea Roger

9. Frontal carinæ very close to each other; antennæ inserted very near the oral margin. Tip of abdomen strongly deflected downward 10

Frontal carinæ of a different conformation, or the tip of the abdomen not deflected 11

10. Clypeus in front projecting in the middle; petiole nodiform (America, Europe, Australia) . . . . * **Sysphincta** Roger

Clypeus not projecting in front; petiole scale-like (America, Europe)
* **Proceratium** Roger

11. Abdomen straight and constricted behind each segment; pygidium impressed or furcate (South America, Australia)
Sphynctomyrmex Mayr

Abdominal segments not constricted 12

12. Body cylindrical with an elongated head, usually with one ocellus on the vertex 13

Of a different conformation 14

13. Antennæ 12-jointed (neotropical) . . . . Cylindromyrmex Mayr

Antennæ 11-jointed (Africa) . . . . Simopone Forel

14. Petiole inserted behind on the postpetiole throughout its whole breadth; antennæ 12-jointed 15

Petiole constricted off from the postpetiole, and separate . . . 21

15. Middle and hind tibiæ without spurs, claws very large, eye well developed (Australia) . . . . Onichomyrmex Emery

Middle and hind tibiæ spurred; eye very small 16

16. Pygidium with a row of prickles on its lateral border; petiole square; antennæ robust (South America) . . . . . Acanthostichus Mayr

Pygidium without prickles on its border 17

17. Very small (at most 2½ mm.); funiculus with a 4-jointed club, only one spur well developed on the middle and hind legs (South America, Australia) . . . . Prionopelta Mayr

Larger, middle and hind tibiæ each with two spurs 18

18. Integument shining 19

Integument at least in part opaque, densely sculptured 20

19. Antennæ very thick, the whole funiculus club-like (Asia, Australia)
Myopopone Roger

Antennæ with filiform funiculus, but slightly thickened towards its tip. (Australia) . . . . Amblyopone Erichson

20. Mandible blunt at its tip or with a spatulate dilatation (Madagascar, India) . . . . Mystrium Roger

Mandible pointed at its tip (America, Europe, Asia, Australia)
* **Stigmatomma** Roger

21. Mandibles inserted on the anterior corners of the head 22
Mandibles inserted in the middle of the anterior border of the head 55
22. Frontal carinæ approximated and almost perpendicular, not covering the insertions of the antennæ. Postpetiole strongly constricted off from the following segment 23
Frontal carinæ more or less dilated, and covering the insertions of the antennæ at least in part; antennæ always 12-jointed 26
23. Petiole sharply margined laterally; last joint of antenna not particularly large (Asia, Australia, Africa) . . . . Phyracaces Emery
Petiole not margined laterally 24
24. Last antennal joint much longer than the penultimate joint, forming a one-jointed club (Asia, Australia, Africa) . Cerapachys F. Smith
The last two or three joints of the antenna form an indistinctly separated club (India) . . . . Lioponera Mayr
25. Frontal carinæ farther from each other than from the sides of the head. Mandibles with very long thorn-like teeth (South America) Thaumatomyrmex Mayr
Frontal carinæ nearer to each other than to the sides of the head; mandibles of a different conformation 26
26. Mandibles slender, when closed first strongly converging, then directed straight forward, beak-like, below with a powerful tooth, eye very large, placed anteriorly (India) . . . . . Harpegnathus Jerdon
Mandibles of a different conformation 27
27. Middle legs with two simple spurs; hind legs with a simple and a pectinate spur (America, Africa, Asia) . . . Centromyrmex Mayr
Spurs of the middle and hind legs of like structure 28
28. Claws pectiniform 29
Claws not pectiniform 30
29. Mandibles slender with a few large teeth along the medial border (Australia) . . . . Prionogenys Emery
Mandibles slender and toothless, or broader with dentate edges (warm regions of the whole world) . . . . **Leptogenys** Roger
30. Antennal fovea continued back into a groove which bends around the eye and is capable of enclosing the antennal scape and a portion of the funiculus (South America) . . . . . Paraponera F. Smith
Of a different conformation 31
31. Margin of clypeus denticulate; pronotum on either side with a tooth-like projection (India) . . . . Odontoponera Mayr
Clypeus not denticulate 32
32. Frontal carinæ not broadened into lobes anteriorly, but only slightly dilated, widely separated from each other; middle and hind legs with well-developed median spur; lateral spur, when present, very small 33
Frontal carinæ converging posteriorly and there usually closely approximated. Anteriorly they are dilated to form a horizontal lobe . 39
33. Antennæ with 3-jointed club; claws simple 34

Antennæ without a differentiated club; claws usually toothed or split 35

34\. Petiole distinctly pedunculate; thorax above with distinct sutures (South America) . . . . Typhlomyrmex Mayr

Petiole not pedunculate; thorax above without sutures (New Guinea) Rhopalopone Emery

35\. Third abdominal segment strongly fornicate dorsally, so that its posterior margin is directed downward, or even somewhat forward; thoracic dorsum without sutures 36

Of a different conformation 37

36\. Eye small; third abdominal segment strongly deflected (South America) Alfaria Emery

Eyes larger; third abdominal segment but slightly deflected (southern Asia) . . . . Stictoponera Mayr

37\. Promesonotal suture obsolete, or distinct as a deep depression, which does not, however, interrupt the sculpture of the integument (South America) . . . . Ectatomma F. Smith

Promesonotal suture distinct and sharply cutting through the sculpture of the integument 38

38\. Antennal fovea elongated backwards as a groove; epinotum with teeth or spines; hind coxa unarmed (South America, Australia) Acanthoponera Mayr

Antennal fovea not elongated posteriorly; epinotum unarmed; hind coxa unarmed (Australia) . . . . . . Rhytidoponera Mayr

Antennal fovea not elongated; epinotum unarmed; hind coxa with a spine (South America) . . . . Holcoponera Mayr

39\. Episternum of mesothorax hollowed out; petiole behind with two teeth or spine (India and Australia) . . . . Diacamma Mayr

Episternum of mesothorax not hollowed out 40

40\. Medial spur of the middle and hind legs alone developed, the lateral spur is lacking, or very small (Trapeziopelta) 41

Both spurs of the middle and hind legs well developed 47

41\. Integument smooth or sculptured, without pubescence 42

Integument delicately sculptured; at least the abdomen pubescent 45

42\. Clypeus in the middle with a slender projecting lobe; lateral spur small but distinct (Malasia and Papuasia) . . . . Trapeziopelta Mayr

Clypeus without a lobe 43

43\. Mandible sickle-shaped, flat and pointed (Africa) Psalidomyrmex André

Mandible slender, with a few teeth on the medial border . . . 44

44\. Mandible obtuse at the end (Africa) . . . Plectroctena F. Smith

Mandible pointed, its medial border with two teeth (Ceylon) Myopias Roger

45\. Clypeus in front with a needle-shaped process (South America) Belonopelta Mayr

Clypeus without a point in front 46

46. Antenna with a 4-jointed club (Asia and Papuasia) Cryptopone Em.
Antenna without a club, or with an indistinctly marked off 5-jointed club (warm and temperate regions of the whole world) * **Ponera** Latr.
47. Clypeus flat, separated from the frontal carinæ by a scarcely perceptible suture or not at all; body opaque, with fine gray pubescence (warm regions of the whole world) . . . . . Platythyrea Mayr
Clypeus separated off by a distinct suture 48
48. Anterior border of clypeus with two teeth 49
Clypeus not bidentate 50
49. Epinotum with two teeth; petiole pointed above (Africa) Streblognathus Mayr
Epinotum unarmed; petiole not pointed (South America) Dinoponera Roger
50. Clypeus in the middle with a raised piece margined on either side (Africa) . . . . Paltothyreus Mayr
Clypeus arched or carinate 51
51. Cheek in front of the eye with a longitudinal carina 52
Cheek without a carina 53
52. Claws dentate (Africa) . . . . Megaponera Mayr
Claws simple (South America) . . . . Neoponera Emery
53. Eye in the middle or behind the middle of the side of the head (Africa) . . . . Ophthalmopone Forel
Eye in front of the middle of the side of the head 54
54. Mesoëpinotal suture obsolete or not impressed; mesonotum not arched in profile (warm regions of the whole world) **Pachycondyla** F. Smith
Mesoëpinotal suture impressed; mesonotum distinctly arched in profile . . . . Euponera Forel
55. Antennal foveæ confluent with each other behind the frontal carinæ; petiole prolonged above into a thorn-like point (warm regions of the globe) . . . . **Odontomachus** Fabricius
Antennal foveæ not confluent behind 56
56. Antennal fovea bordered by a carina laterally behind the eye; head not emarginate posteriorly; petiole pointed (Madagascar) Champsomyrmex Emery
Antennal fovea without a lateral keel behind the eye; head always emarginate posteriorly; petiole usually not pointed * Anochetus Mayr

3d Subfamily: Myrmicinæ.

1. Clypeus not prolonged back between the frontal carinæ,[1] which are closely approximated to each other; antennæ 12-jointed (tribe Pseudomyrmii) 2

[1] In some species of Pseudomyrma the clypeus seems to be continued back narrowly between the frontal carinæ, but this prolongation is the equivalent of the frontal area; it is often distinct from the clypeus.

Clypeus almost always prolonged between the frontal carinæ, which are more or less separated; in the opposite case, the antennæ are 11-jointed 3

2. Clypeus suddenly descending in front, or as if inflected or subtruncated, usually armed with teeth at the level of this inflection; rarely it is uniformly sloping and deeply emarginate at the anterior border (Africa, Asia, Oceanica) . . . . Sima Roger

Clypeus neither inflected nor dentate, not or only feebly emarginate (America) . . . . **Pseudomyrma** Guerin

3. Antennæ 7-jointed, without a distinct club (13-jointed in the male); frontal carinæ, as usual, distant from the lateral borders of the head; thorax spinose (tribe Myrmicarii) . . . . Myrmicaria Saunders

Antennæ of a different conformation (when 7-jointed, the last joint is enlarged or forms part of a differentiated club, or the scape may be enclosed in a deep groove, or the thorax is without spines) . . 4

4. Antennal fovea or groove placed at the side of the head; the carina formed by its dorsal margin (and which does not correspond to the frontal carina of other ants) passes outside of the eye; posterior angles of the head pointed or prolonged or denticulate; antennæ 11-jointed in all the sexes (tribe Cataulacii) . Cataulacus F. Smith

Of a different conformation 5

5. The antennal fossæ terminate behind on the sides of the head, pass above the eye and are sufficiently deep to conceal the whole antennal scape; antennæ 11-jointed, without differentiated club; gizzard fungiform, of peculiar structure (tribe Cryptocerii) (America) . . . 6

Antennal fossæ differently placed, or the antennæ of a different conformation; gizzard of the usual form 7

6. Antennal foveæ approximated in front, diverging strongly behind, not reaching the sides of the head except at their extremities Procryptocerus Emery

Antennal foveæ covered throughout their length by the lateral border of the head . . . . **Cryptocerus** Fabricius

7. Postpetiole articulated to the dorsal surface of the following segment (tribe Crematogastrii) . . . . * **Crematogaster** Lund

Postpetiole inserted at the anterior end of the following segment . 8

8. Head cordiform, emarginate behind, with the posterior angles strongly rounded and devoid of spines; last joint of antennæ very much smaller than the preceding joint (tribe Dacetii) 9

Head of a different conformation 15

9. Antennal foveæ short; antennæ 11-jointed 10

Antennal foveæ as long as the scape 11

10. Only the last joint of the antennæ longer than the preceding joint Daceton Perty

Last two joints of the antennæ longer than the preceding Acanthognathus Mayr

11\. Antennal foveæ shallow, at the medial side of the eye; antennæ 5-jointed, the third much elongated . . . Orectognathus F. Smith
Of a different conformation 12
12\. Antennal foveæ placed at the dorsal or medial side of the eyes . 13
Antennal foveæ placed at the lateral side of the eyes 14
13\. Antennæ 6-jointed . . . . * **Strumigenys** F. Smith
Antennæ 4-jointed . . . . * Epitritus Emery
14\. Antennæ 6-jointed . . . . Epopostruma Forel
Antennæ 7–8-jointed . . . . Rhopalothrix Mayr
Antennæ 12-jointed . . . . Ceratobasis F. Smith
15\. Antennæ 11-jointed, without distinct club, or a club consisting of a single joint (tribe Attii, America) 16
Club of several joints, or the antennæ not 11-jointed 20
16\. Frontal carinæ very close to each other and dilated at the anterior extremity; clypeus not distinctly prolonged between them . . 17
Frontal carinæ separated, embracing the posterior extremity of the clypeus 18
17\. Integument opaque and even, bristling with long, fine hairs
Apterostigma Mayr
Integument bristling with tubercles and spines, with hooked and scale-like hairs . . . . Myrmicocrypta F. Smith
18\. No erect hairs on the body; antennal foveæ usually prolonged to the posterior corners of the head . . . . . . **Cyphomyrmex** Mayr
Body bearing erect hairs 19
19\. Integument even, bearing only delicate oblique hairs
Sericomyrmex Mayr
Integument rough, bearing stiff or hooked hairs . . **Atta** Fabricius
20\. The shallow antennal foveæ bordered laterally by an abrupt carina; antennæ 11-jointed, with a club of three joints, the last of which is decidedly predominant 21
Of a different conformation 22
21\. Clypeus transversely arched, almost straight in a longitudinal direction
Ochetomyrmex Mayr
Clypeus arched both longitudinally and transversely Wasmannia Forel
22\. Club of the antennæ 2-jointed, the last joint much larger than the other (tribe Solenopsidii and the genus Phacota) 23
Antennal club of a different conformation or indistinct 28
23\. Antennæ 9-jointed (10-jointed in the female and 13-jointed in the male)[1]; no dimorphism among the workers . Carebara Westwood
Antennæ 12-jointed . . . . Adelomyrmex Emery
Antennæ 10- or 11-jointed 24

[1] Professor Forel refers to the genus Oligomyrmex Mayr, the worker of which is unknown, an undescribed Australian species with strongly dimorphic workers. The antennæ are 9-jointed, as in Carebara worker and in Oligomyrmex female.

24. Antennæ 10-jointed 25
Antennæ 11-jointed 26

25. Dimorphism of the workers usually but slightly marked, or, in the opposite case, the head of the worker major is subquadrate or broader than long (antennæ 10- to 11-jointed in the female) . *** Solenopsis** Westwood
Dimorphism of the workers very marked; head of the worker major elongated (antennæ 11-jointed in the female) . Aëromyrma Forel

26. Thoracic sutures indistinct . . . . * Phacota Roger
Mesoëpinotal suture strongly marked 27

27. Ninth antennal joint conspicuously longer than the eighth, though much shorter and especially narrower than the tenth Diplomorium Mayr
Ninth joint of the antennæ not distinctly longer than the eighth; workers polymorphic; soldiers with enormous heads Pheidologeton F. Smith

28. Antennal foveæ deep, capable of containing the whole scape, and placed along the sides of the head 29
Antennal foveæ less deep or differently placed 30

29. Antennæ 9-jointed (10-jointed in the male as in Tetramorium); mesonotum with a blade-like posterior edge and usually armed with spines Meranoplus F. Smith
Antennæ 11-jointed, the last joint very large . Calyptomyrmex Emery

30. Erect hairs on the body trifid . . . . * Triglyphothrix Forel
Hairs not trifid 31

31. Posterior border of the clypeus raised in the form of a trenchant ridge which borders the antennal foveæ in front 32
Posterior border of the clypeus not forming a ridge 38

32. Mandibles pointed, without apical border . * Strongylognathus Mayr
Mandibles with dentate apical border 33

33. Portion of the clypeus in front of the antennal insertion narrow, but not reduced to a mere ridge (antennæ of the male 10-jointed) (forming with the four preceding genera the tribe Tetramorii) . . . 34
Portion of the clypeus in front of the antennal insertion reduced to a trenchant ridge (antennæ of male 13-jointed) 37

34. Antennæ 12-jointed 35
Antennæ 11-jointed 36

35. Epinotum armed with spines or teeth . . . . *** Tetramorium** Mayr
Epinotum rounded, unarmed . . . . Rhophomyrmex Mayr

36. Thoracic dorsum deeply impressed at the mesoëpinotal suture Dacryon Forel
Thoracic dorsum scarcely or not at all impressed at the mesoëpinotal suture . . . . **Xiphomyrmex** Forel

37. Antennæ 11-jointed . . . . Pristomyrmex Mayr
Antennæ 12-jointed 38

38. Petiole pedunculate in front; dimorphism of the workers very marked Acanthomyrmex Emery
Petiole not pedunculate in front; no appreciable dimorphism in the workers . . . . * **Myrmecina** Curtis
39. Antennæ 7–10-jointed, the last joint very large; thorax without spines or teeth; eyes present . . . . Allomerus Mayr
Antennæ 10–12-jointed; when there are ten, the eyes are wanting or the epinotum is armed with two spines 40
40. Without eyes 41
With eyes, sometimes small, but quite distinct 43
41. Antennæ 12-jointed, without distinct club; insects very small * Leptanilla Emery
Antennæ 10–11-jointed, with 3-jointed club 42
42. Postpetiole armed with a spine on its lower surface Liomyrmex Mayr
Postpetiole unarmed; size very small *Monomorium decamerum* Emery
43. Antennæ 11-jointed 44
Antennæ 12-jointed (10-jointed in *Pheidole perpusilla* Emery) . . 55
44. Thorax and petiole without any trace of teeth or spines; pronotum never angular 45
Metanotum nearly always armed with teeth or spines; when they are absent, the pronotum has angular humeri 48
45. Clypeus bidentate in front 46
Clypeus unarmed 47
46. Petiole distinctly pedunculate in front . . . . * **Monomorium** Mayr
Petiole not pedunculate . . . . **Xenomyrmex** Forel
47. Thorax unarmed, impressed in the region of the mesoëpinotal suture Vollenhovia Mayr
Thorax armed with spines and without an impression at the mesoepinotal suture . . . . Stereomyrmex Emery
48. Eyes prolonged obliquely downwards and forwards Oxyopomyrmex André
Eyes round or oval 49
49. Thoracic dorsum profoundly impressed at the mesoëpinotal suture 50
Thoracic dorsum little or not at all impressed 52
50. Humeri of pronotum rounded . . . . Huberia Forel
Humeri of pronotum angular 51
51. Antennal club 3-jointed, at least as long as the remainder of the funiculus . . . . Lophomyrmex Emery
Club indistinct, the last three joints much shorter than the remainder of the funiculus . . . . Podomyrma F. Smith
52. Frontal carinæ as long as the antennal scape . * **Tomognathus** Mayr
Frontal carinæ much shorter than the scape 53
53. Workers strongly dimorphic; integument shining, petiole pedunculate Machomyrma Forel[1]

[1] This group was established by Professor Forel as a subgenus of Liomyrmex; it has seemed to me to deserve elevation to the rank of a genus.

Workers not dimorphic 54

54. Petiole scarcely pedunculate in front, postpetiole armed below with a spine,[1] integument in great part smooth and shining

* Formicoxenus Mayr

Petiole with a short peduncle, postpetiole unarmed below; body in great part opaque . . . . * **Leptothorax** Mayr

55. Workers dimorphic, usually without forms intermediate between the large-headed soldiers and the workers; antennal club 3-jointed, longer than the remainder of the funicle (4-jointed in *Ph. granulata* Pergande); sting very feeble . . . . . . **Pheidole** Westwood

Workers monomorphic or dimorphic; in the latter case the extreme forms are connected by intermediates, and the antennal club is usually indistinct or shorter than the remainder of the funiculus 56

56. Petiole armed with spines above[2] 57

Petiole without a spine 58

57. Petiole with one spine . . . . Lordomyrma Emery

Petiole with two spines . . . . Atopomyrmex André

58. The last three joints of the antennæ are much shorter than the remainder of the funiculus and do not form a very distinct club 59

The last three joints of the antennæ form together a club about as long as the rest of the funiculus 63

59. Thoracic dorsum impressed at the mesoëpinotal suture; promesonotal suture usually distinct 60

Thoracic dorsum without any trace of suture or impression . . . 62

60. Posterior spurs pectinated . . . . * **Myrmica**

Posterior spurs simple or absent 61

61. Middle of clypeus projecting in an angle; epinotum unarmed, with a median impression which can receive the petiole; integument in great part shining (America) . . . . . Megalomyrmex Forel

Middle of clypeus angular in front; epinotum armed with spines; antennæ thick (Madagascar) . . . . . . Eutetramorium Emery

Clypeus of a different conformation, epinotum usually armed with teeth or spines (always without spines in Holcomyrmex)

* **Stenamma** Westwood

* Holcomyrmex Mayr[3]

62. Posterior spurs simple; petiole very long (Africa) Ocymyrmex Emery

Posterior spurs pectinated (America) . . . . **Pogonomyrmex** Mayr

[1] In *F. corsicus* Emery, the worker of which is unknown, the postpetiole of the female has only an obtuse tooth.

[2] In *Atopomyrmex ceylonicus* and *nodifer* the node of the petiole is merely angular in front.

[3] All the characters of the genus Holcomyrmex are found singly in one or the other forms of the genus Stenamma as I have defined this genus in my work on the ants of North America (*Zool. Jahrb. Syst.*, Bd. viii, p. 297). The teeth of the clypeus are indistinct in *H. muticus* Emery.

63. Clypeus armed with two ridges, which project forward in the form of teeth, rarely without teeth, but then the epinotum is quite unarmed; mesoëpinotal suture marked . . . . . . * **Monomorium** Mayr
   Clypeus of a different conformation; rarely 2-toothed, but then the mesoëpinotal suture is indistinct 64
64. Inferior angles of the pronotum pointed . . . . . Rogeria Emery
   Inferior angles of the pronotum rounded 65
65. Postpetiole campanulate, attached throughout by means of its whole posterior surface to the following segment; thoracic dorsum with neither suture nor impression . . . . . . **Macromischa** Roger
   Postpetiole distinctly constricted posteriorly 66
66. The abdomen, seen from the side, is triangular; its anterior angle attached to the postpetiole; epinotal spines recurved forwards Trigonogaster Forel
   Of a different conformation 67
67. Without erect hairs, petiole pedunculate, with a rounded node; postpetiole usually very large . . . . . . * Cardiocondyla Emery
   With erect hairs; which are usually clavate and microscopically denticulate . . . . * **Leptothorax** Mayr

The following genera are not included in this table: * Anergates Forel and **Epœcus** Emery, parasitic ants, which have no workers; Trichomyrmex Mayr, Tranopelta Mayr, * Oligomyrmex Mayr, Rhopalomastix Forel, Cratomyrmex Emery, of which the workers are unknown; and finally Pheidolacanthinus F. Smith, which was insufficiently characterized by its author and is unknown to me in nature.

4th Subfamily: DOLICHODERINÆ.[1]

1. Sting well developed; petiole with a long peduncle in front Aneuretus Emery
   Sting rudimental; petiole squamiform or nodiform, not pedunculate in front 2
2. Chitinous integument stiff and brittle, often strongly sculptured; thorax and scale often spinose or angular; gizzard without a calyx and with delicate cuticle, not furnished with cilia at the entrance * **Dolichoderus** Lund
   Integument thin and flexible, finely sculptured; thorax and petiole never spinose; gizzard of a different conformation 3
3. Body very slender; legs and antennæ much elongated, large or medium-sized species; gizzard without a calyx, furnished with cilia at the entrance (Australia) . . . . Leptomyrmex Mayr

[1] The genera of the Dolichoderinæ are in large part established on anatomical characters (structure of the gizzard) and the wing neuration; this renders the identification of isolated workers very difficult.

Body less slender ; species nearly always small ; gizzard with a reflected calyx 4

4. Eyes very large, occupying one-third the side of the head
Turneria Forel

Eyes much smaller 5

5. Cloacal orifice apical ; petiole very low, without a distinct scale
Technomyrmex Mayr

Cloacal orifice inferior 6

6. Scale of petiole very small and strongly inclined, or even altogether absent 7

Scale more or less inclined, but well developed 9

7. Maxillary palpi 2–4-jointed, labial palpi 2–3-jointed ; in the anterior wing of the female and male the transverse nervure joins the external branch of the cubital nervure (Europe, India, Australia)
* Bothriomyrmex Mayr

Maxillary palpi 6-jointed, labial 4-jointed 8

8. Scale of petiole small but distinct in the worker (well developed in the female) ; in the anterior wing the transverse vein joins the external branch of the cubital vein ; there is no closed cubital cell in the male, one only in the female ; no discoidal cell ; gizzard with a convex, 4-lobed calyx (a monotypic American genus) **Forelius** Emery

Scale rudimental or none ; the transverse vein joins the cubital at the point of bifurcation ; a single closed cubital cell, usually a single discoidal ; gizzard with a depressed calyx without lobes
* **Tapinoma** Foerster

9. Metanotum bearing a conical projection more or less distinctly developed ; wings as in Forelius (American species) **Dorymyrmex** Mayr

Metanotum of a different conformation ; wings with a discoidal cell 10

10. Gizzard very short, with a great reflected calyx ; no ocelli, stature but slightly variable . . . . Iridomyrmex Mayr

Gizzard at least as long as broad ; stature highly variable ; ocelli usually present in the large workers 11

11. Thorax not impressed at the mesoëpinotal suture ; no remarkable dimorphism in the workers ; wings with two closed cubital cells
* **Liometopum** Mayr

Thorax impressed at the mesoëpinotal suture ; workers often remarkably dimorphic ; with a single closed cubital cell ; transverse vein meeting the bifurcation of the cubital (American species)
Azteca Forel

The genus Linepithema Mayr, of which only the male is known, is not included in the above table.

5th Subfamily: CAMPONOTINÆ.

1. Mandibles long, linear, denticulate; eyes very large Myrmoterus Forel
   Mandibles of a different conformation 2
2. Antennæ 11-jointed, or less 3
   Antennæ 12-jointed 10
3. Clypeus projecting forward above the mandibles, eyes lateral, enormous, antennæ 8-jointed . . . . Gesomyrmex Mayr
   Of a different conformation 4
4. Last joints of the antennæ forming a differentiated club; antennæ 9–10-jointed . . . . Myrmelachista Roger
   Antennæ without a differentiated club 5
5. Frontal carinæ separated from each other by a greater distance than from the lateral borders of the head 6
   Frontal carinæ closer to each other than to the lateral borders of the head 7
6. Eyes reniform, very large . . . . . Dimorphomyrmex Er. André
   Eyes oval, of medium size . . . . Aphomomyrmex Emery
7. Maxillary palpi 2-jointed, labial palpi 3-jointed . . Acropyga Roger
   Maxillary palpi 6-jointed, labial palpi 4-jointed 8
8. Metanotum and scale more or less 2-toothed or 2-spined
   * Acantholepis Mayr
   Metanotum and scale unarmed 9
9. Antennæ 11-jointed (Old World species) . . . * Plagiolepis Mayr
   Antennæ 9-jointed, exceptionally 11-jointed; thorax short and thick-set (American species). . . . . **Brachymyrmex** Mayr
10. Eyes very large, occupying nearly the whole of the sides of the head
    Gigantiops Roger
    Eyes occupying less than one-half of the sides of the head . . . 11
11. Prothorax with an angular crest on either side; mesonotum prominent, in the form of a boss; gizzard as in Plagiolepis Notoncus Emery
    Thorax of a different conformation 12
12. Antennæ inserted some distance behind the clypeus; gizzard with long straight sepals 13
    Antennæ inserted very near the posterior edge of the clypeus . . 20
13. Maxillary palpi 5-jointed; petiole elongate, narrow; stature variable, but not dimorphic in the form of the head . Œcophylla F. Smith
    Maxillary palpi 6-jointed; petiole short, squamiform or nodiform, often spinose or dentate 14
14. Dimorphism clearly marked in the size, form, and often in the sculpture of the head; stature usually very variable . . * **Camponotus** Mayr
    No marked dimorphism in the workers 15
15. Eyes placed towards the posterior angles of the head
    Opisthopsis Emery
    Eyes on the sides of the head 16

16. Thorax and petiole without spines or teeth 17
Thorax and petiole, or the latter alone more or less spinose or dentate 18
17. Body thickset; head rounded behind (Australia, Papuasia)
Calomyrmex Emery
Body slender; head narrowed behind (America)
Dendromyrmex Emery
18. Body thickset; thorax without spines, its anterior angles rounded; petiole prolonged into a point on either side . Echinopla F. Smith
Body less thickset; thorax usually dentate or spinose (when this is not the case the body is shining jet black, and the scale of the petiole is quadridentate) 19
19. In profile, the mesonotum occupies the bottom of a deep cleft overarched by the metanotum; eyes supported laterally by a lobe of the head in the form of a blinder (œillère) . . . Hemioptica Roger
Mesonotum not depressed; eyes usually free, rarely with a distinct blinder . . . . * Polyrhachis F. Smith[1]
20. The last 4 to 5 antennal joints distinctly differentiated to form a club
Myrmecorhynchus Er. André
No differentiated club 21
21. Calyx of gizzard reflected and surrounded by a muscular ring as in Plagiolepis (Australia, New Zealand, Chile) . Melophorus Lubbock
Sepals of calyx distinct and little or not at all reflected (except * Prenolepis, none of these genera are found in Australia or Chile) . 22
22. Clypeal fovea distinctly separated from the antennal fovea
* **Prenolepis** Mayr
Clypeal fovea confluent with the antennal fovea, or feebly separated in Pseudolasius 23
23. Joints 2–5 of the funiculus shorter or not longer than the succeeding joints; ocelli usually absent 24
Joints 2–5 of the funiculus longer than the succeeding joints; ocelli distinct 25
24. Mandibles long, with oblique dentate blades; dimorphism very marked; head large in the worker major; clypeal fovea slightly separated from the antennal fovea (Sunda Islands and Moluccas)
Pseudolasius Emery
Mandibles shorter, with less oblique blades; dimorphism scarcely or not at all perceptible (holarctic region) . . . * **Lasius** Fabricius
25. 4th joint of maxillary palpi nearly twice as long as the 5th
* **Myrmecocystus** Wesmael
4th joint of the maxillary palpi a little longer than the 5th . . . 26
26. Mandibles with the apical margin broad and denticulate * **Formica** Linne
Mandibles narrow and pointed . . . . . . * **Polyergus** Latreille

[1] *P. simplex* Mayr has been found in Palestine. Mr. Edward Saunders sent me a specimen the provenience of which appears to be authentic.

ADDENDA.

Since the manuscript of the preceding paper was received, Professor Emery has made some changes in the subdivision of the genus Cerapachys.[1] He now divides this genus into five subgenera as follows: (1) Cerapachys (*sensu stricto*), with 12-jointed antennæ; (2) Parasyscia, with 11-jointed antennæ; (3) Oöceræa, with 10-jointed antennæ; (4) Syscia, with 9-jointed antennæ and the basal segment of the gaster but little longer than the postpetiole; (5) Cysias, with 9-jointed antennæ and the basal gastric segment very large. The more homogeneous genus Phyracaces is not cut up into subgenera.

In another recent paper[2] Emery describes a new genus, Ænictogiton, based on a male specimen of a peculiar doryline ant from the Congo (*A. forsiceps* Emery). As the name indicates, this insect is allied to Ænictus.

As a further addition, I may mention that Forel[3] has very recently described a remarkable new genus of Ponerinæ from Haiti under the name Emeryella. It resembles the extraordinary genus Mystrium in the structure of its mandibles. In other respects it is allied to Ectatomma. The following is a translation of Forel's diagnosis:

"**Emeryella** gen. nov.

"Mandibles, at first sight, very similar to those of the genus Mystrium, but without the two rows of teeth along their inner borders. They are linear, slightly depressed, longer than the head, feebly curved inwards, especially at their distal half, the basal half being nearly straight. Their bases are a little longer than their tips, which are obliquely truncated. There are only three teeth on the mesial border; the first is very broad, short, and obtuse, and not far from the base; the second, situated in the middle, is short and obtuse; the third is still smaller, and near the tip. The mandibles are nowhere canaliculated. They are inserted, like those of Mystrium, on the widely separated anterior angles of the head, so that they enclose a large empty space.

[1] Note mirmecologiche, *Rendiconto delle Sess. della R. Accad. delle Scienze dell' Istituio di Bologna* (Nov. 17, 1901), pp. 3–15.

[2] Note sulle Doriline, *Bull. della Soc. Ent. Ital.*, anno xxxiii, trim. 1 (1901), pp. 43–63.

[3] Variétés myrmécologiques, *Ann. Soc. Ent. Belg.*, tome xlv (1901), pp. 334–382.

" Apart from the above, all the characters are very similar to those of Ectatomma, especially of the subgenus Gnamptogenys. Antennæ 12-jointed. Eyes large, lateral. Frontal carinæ widely separated, short. Clypeus rounded behind. Promesonotal suture only slightly visible. Mesometanotal suture very deep, constricted. Pedicel of the abdomen like that of Gnamptogenys. Middle and hind legs with but a single spur, which is pectinated. Tarsal claws bidentate.

" This genus is undoubtedly very closely related to Ectatomma; but the structure of the mandibles is so peculiar and recalls so forcibly the group of Mystrium and Myrmecia that I feel fully justified in establishing the genus."

The type of the genus Emeryella is *E. Schmitti* Forel.

W. M. WHEELER.

PECULIAR STAGES OF FOLIAGE IN THE GENUS ACACIA.

CARLETON E. PRESTON.

The development of foliage leaves in general appears, from the results of investigations made thus far, to be a regular increase in complexity, almost the same for the ontogeny of a single plant as for the race in historic development, as disclosed by fossil remains. As an especially good example may be mentioned a series given by Jackson ('99) illustrative of the history, both phylogenetic and ontogenetic, of Liriodendron. For the genus Acacia, Reinke ('96) gives a very comprehensive review of the development based upon the seedling forms and comparative study of the adults of the several subgenera, noting especially the phyllode-forming tendency.

As the first point which this paper aims to bring out deals with the bipinnate leaf and its development regardless of the phyllode, it may be well to call to mind the regular course of seedling leaf forms. The first leaf, after the cotyledons, is normally singly pinnate, with about four pairs of leaflets; the next is generally bipinnate, with but a single pair of pinnæ; further change is a mere addition of more such pairs along the main axis. A peculiar transition stage between the singly pinnate and the bipinnate is sometimes found in seedlings of *A. leprosa* Sieber when growing under cultivation. The shadow prints (Figs. 1 and 2) annexed show the nature of this peculiarity. The lower pair of leaflets only is replaced by a pair of strongly developed pinnæ, while the rest of the axis runs on singly pinnate and rather weak in structure. As a rule, no such continuation of the main axis is to be found.

In the case of Liriodendron, Jackson found some stages which could be regarded as progressive beyond the normal condition of the present species. Here the complexity was increased simply by augmentation of the number of lobes to the leaf.

This augmentation, as has often been shown, takes place in Acacias in the passage from the customary seedling leaf to the majority of bipinnate adults, a large number of pinnæ being added before the full-sized leaf is reached. But this mere addition of pinnæ scarcely seems to be the right interpretation of the increase in complexity if one compares the seedlings of Liriodendron and Acacia. What corresponds to the increase of lobes in the former is not so much the addition of pinnæ in the latter as the increase in degree of pinnation. Starting with a singly pinnate leaf, one arrives at a bipinnate form of remarkably fine structure in such species as *A. decurrens* Willd. But may there not exist a tendency toward triple pinnation in some of the forms? This question, suggesting itself, led to a rather careful search for evidence in its favor, with the result that in *A. decurrens* not a few leaves were discovered in which such a tendency was manifest. Of one of these leaves a shadow print is given (Fig. 3), showing clearly the third degree of pinnation on some of the basal leaflets of the pinnæ. How much of a prophecy this is of a fully tripinnate leaf in certain Acacias of some future epoch no one can really tell; the tendency, however, cannot be without significance.

Fig. 1. — Seedling of *A. leprosa*, showing abnormal third leaf. (Natural size.)

In his paper, which deals with animals as well as with plants, Jackson carries the same principle so far involved one step in advance in point of application. As a leaf develops base and tip first of all, he reasons that any change in shape which may add to its complexity will not appear at those points, but rather upon the proximal portions of the lamina. This he shows to be the case in Liriodendron, citing also several other examples in substantiation of his view.

In the case of the *A. leprosa* seedlings with abnormal development the lateral pinnæ may be regarded as further modifications of the proximal pair of leaflets of the ordinary first leaf of seedlings.[1] If this is, as seems probable, the right interpretation of such peculiar forms, it almost necessarily follows that the change in all the species at this stage is of the same nature, and that as a rule the higher, or more distal, leaflets upon the main axis lose the power to develop, on account of the greater strength of the newly developed lateral pinnæ. It may be worth while to state that these stages were found only after their prediction as the result of a course of reasoning, and were the direct objects of the search which led to their discovery.

FIG. 2. — Abnormal seedling of *A. leprosa*. (Natural size.)

The tendency toward triple pinnation is likewise, as may be easily seen by reference to the figure, only present upon the proximal leaflets of the pinnæ, and not at all to be found on the pinnæ near the tip of the leaf.

The final point to be discussed is the gradual metamorphosis to the phyllode. In seedlings where the change is gradual, as is the case in the great majority of species, but one pair of pinnæ is present at the time of its occurrence. In the abnormal seedlings shown, the prolongation of the axis is suppressed as the transition stages appear. In such cases it is possible to say with a high degree of certainty that the phyllode represents merely the flattened petiole. Next to be considered are the conditions of such forms as experience these changes later in life. *A. rubida* A. Cunn. and *A. heterophylla* Willd. have already been described by Reinke, and in his article one stage in the transition as it occurs in *A. heterophylla* is figured.

[1] *Cf.* seedling of Gleditsia, where such transition stages are frequent.

According to that author the change is merely a gradual flattening of the petiole, accompanied by the reduction of parts more distal. The stage represented in his paper is explained in the following words: "Wo es zu breiten Phyllodien mit nur einem Fiederpaar an der Spitze kommt, entsprach in den von mir gesehenen Fällen das Phyllodium einem nur oberseits geflügelten Blattstiel, das Fiederpaar dem untersten Fiederpaar eines Fiederblattes, Spindel und höhere Fiederpaare würden somit als abortirt anzusehen sein. Steht auf der Spitze eines Phyllodiums einmal ein zweipaariges Fiederrudiment, so pflegt die Spindel zwischen den beiden Fiederpaaren ungeflügelt zu bleiben" (p. 568).

Reinke is naturally giving only the results of his own observations, yet one cannot but draw the inference that a certain law is at least suspected, *viz.*, that only the petiole flattens in each case, and that at the same time the distal parts gradually cease to develop, until at last the stage is reached which this writer figures, after which the last pair of pinnæ fails to develop, and the phyllode is complete.

In the botanic garden of Harvard University there are two species of Acacia which show these transition stages in great abundance. They agree well in leaf characters with *A. rubida* and *A. heterophylla*, and will be discussed under these names, though full identification was not possible, owing to absence of flowers and fruit. Whether or not the determinations are right, the principle which they illustrate remains the same. Of both of these species the writer made a special examination during the spring of 1900, with a view to observing the different transition stages, their sequence and character. Upon re-reading Reinke's article in the summer of 1901, and finding there certain statements which in a way did not correspond with his results, he repeated the examination and ran across more peculiar forms which tend rather to disprove than to confirm the existence of any law governing such changes.

The first thing which appeared from these two examinations was that the method of reduction of the more distal parts described by Reinke, though indeed frequent, is perhaps not the most common of all. Rather more often an equal decrease

in size and final simultaneous disappearance of all the pairs of pinnæ was noted, as opposed to an unequal reduction starting

Fig. 3. — Leaf of *A. decurrens* showing tendency toward a triple pinnation. (Slightly reduced.)

at the distal end. In this *A. rubida* seemed to be very regular; in *A. heterophylla* various methods of change were shown. As

far as sequence is concerned, there appeared to be no definite order, series of transition stages running in both directions.

There was also found a fairly large number of stages which lead one to doubt greatly whether in all cases it is the petiole only which is transformed to the phyllode, and whether, if one pair of pinnæ persists at a certain stage, that pair is always the proximal one. The prints which follow may, to be sure, represent mere anomalies, but from their number, at least, they cannot but raise in one's mind a certain amount of hesitation to

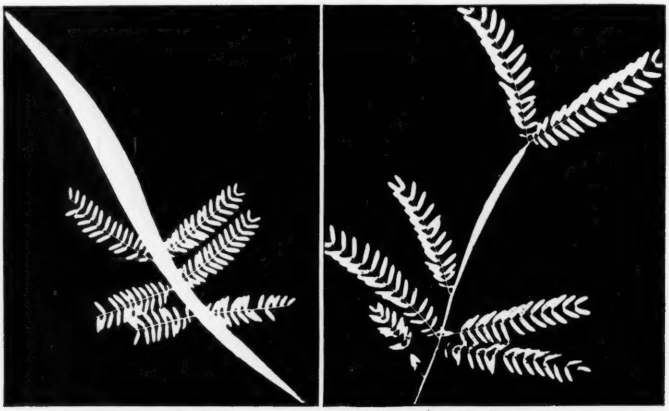


FIG. 4. FIG. 5.

FIGS. 4 and 5.—*A. heterophylla*, variation in transition to phyllode. (1/4 natural size.)

consider the existence of a law as to method in any way established. Here the flattening appears in some cases entirely on the distal portions without affecting the petiole, in others both petiole and rachis are involved to varied extents. How these are to be interpreted under one definite law seems incomprehensible.

It is hardly to be expected, however, that the process of reduction of parts is going to follow the same strictly regular line as that of advancement. The two are brought about by entirely different causes and are in no way comparable. Therefore the fact that such changes as those last described occur does not greatly invalidate the testimony of the earlier presented

data in support of a principle dealing with a progression. On the whole, the conditions of the seedlings of *A. leprosa* and of the leaf of *A. decurrens* stand strongly in favor of the existence

Fig. 6.

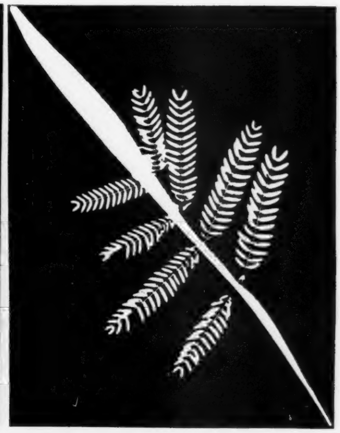


Fig. 7.

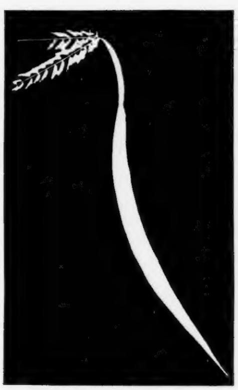


Fig. 8.

Fig. 9.

Fig. 10.

Figs. 6–10. — *A. heterophylla*, variations in transition to phyllode. (1/4 natural size.)

of a regularly increasing complexity in leaf form, governed by fixed laws and repeated in an abbreviated form in plant ontogeny. To a certain extent also they add weight to Professor

Jackson's theory regarding stages in the development of a single leaf. The peculiar phyllode form rather discourages the idea of formulating any law covering phyllode formation, and lends an extremely potent meaning to Reinke's statement, "Der Wechsel von Phyllodien und Fiederblättern ist bei dieser Art [probably, as regards phylogeny, in others also] ein sehr mannigfaltiger."

REFERENCES.

'99. JACKSON, R. T. Localized Stages in the Development of Plants and Animals. *Mem. Bost. Soc. Nat. Hist.* Vol. v, pt. iv.

'96. REINKE, J. Untersuchungen über die Assimilationsorgane der Leguminosen. *Pringsheim's Jahrb. f. wiss. Bot.* Bd. xxx. 70 pp.

THE RELATION OF WIND TO BIRD MIGRATION.

C. C. TROWBRIDGE.

THE influence of meteorological conditions on the migration of birds has been studied by a number of observers. Among the important monographs on the subject is that of Prof. W. W. Cooke, "Bird Migration in the Mississippi Valley," in which it is shown clearly that migratory waves of birds accompany changes of temperature. The wind directions and velocities were recorded in the paper mentioned but the author did not regard the migratory movements to be due to the direct effect of the wind, which was considered merely as the chief cause of the temperature changes.

The same view is held by Dr. W. Stone in his "Birds of Eastern Pennsylvania and New Jersey," in which by a series of curves the fact is illustrated that migratory waves of birds follow closely changes of temperature.

The author of the present paper believes that the bird waves described by the above observers were largely due to the direct influence of favorable winds, and that the wind is a more important factor in bird migration than it is generally regarded.

That the subject has not received much attention is shown by the recent valuable review on bird migration by Dr. F. H. Knowlton in *Popular Science Monthly*.[1] In the paper referred to no mention of the relation of the wind to bird migration is made. In fact, the word "wind" is not used in the thirteen pages of the article.

In considering the relation of meteorology to bird migration, general as well as local atmospheric conditions must be studied, and it is important that the atmospheric conditions where the birds start on their migratory journeys be determined, if possible. Furthermore, the number of new arrivals

[1] Knowlton, Dr. F. H. The Journeyings of Birds, *Pop. Sci. Mon.*, vol. lx, No. 4, p. 323.

recorded in any locality is not always a safe criterion of the migratory movement of birds, because adverse meteorological conditions often tend to retard or stop the migrations and bring certain species under notice which, with favorable conditions, would have passed by unobserved.

A previous paper by the author, "Hawk Flights in Connecticut,"[1] contained an account of flights of hawks which had occurred along the southern border of Connecticut during the autumn migrations, in which the results were presented of observations covering a period of nine years, from 1885 to 1894.

The present paper is an account of further observations on the migrations of hawks and on the effect of the wind on the migrations of various other species of birds. It is necessary to refer to the contents of the previous paper on the subject, and the principal facts given in it are as follows:

It was shown that flights of hawks occurred in September of almost every year in southern Connecticut, consisting of different species, some of which passed along the coast singly, others in flocks of from twenty to two hundred. The hawks were most numerous at from one half to one mile inland from Long Island Sound, along the first low hills back from the coast.

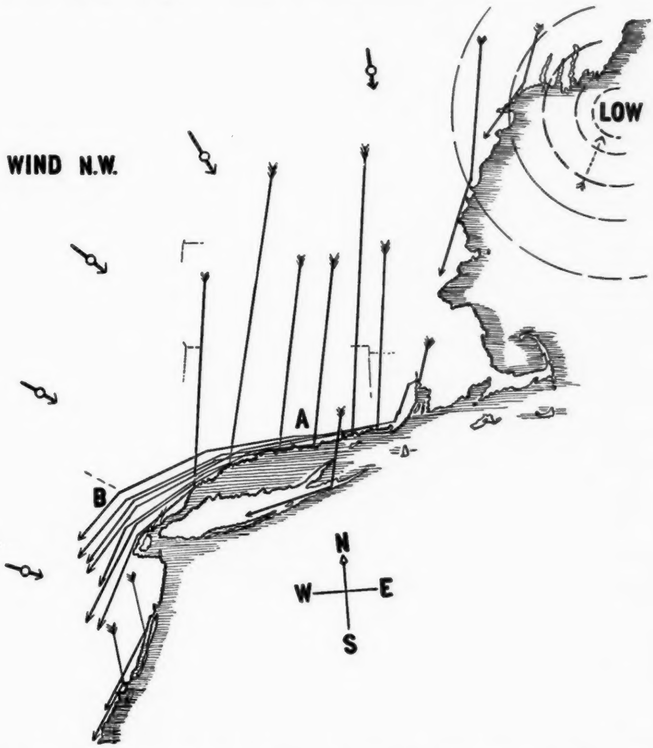
Twenty-two hawk flights were recorded in nine years, and in each case notes were made on the relative abundance of the different species of hawks seen migrating. A record was kept of the meteorological conditions on the days when the flights in question took place. It was found that on the days when the flights occurred the wind blew from the north or northwest, and usually with considerable velocity. On seven days the wind blew at the rate of over twenty miles an hour, and on eight other days not less than fifteen miles. The greatest flights occurred on three days, when the velocity of the wind was about forty miles per hour during part of the day.

An explanation of the cause of these autumn flights of hawks was given, and the theory advanced has been fully verified by

[1] *The Auk*, July, 1895.

subsequent observations. The cause of the flights was stated to be as follows:

Hawks drift with the wind when soaring, and as they soar continually, their movements during migrations are largely dependent on the direction of the wind. In the present case hawks migrating in autumn in New England drift south or



MAP I. — COAST LINE OF THE NEW ENGLAND STATES AND NEW JERSEY.

The long arrows indicate the general direction of migration of hawks and many other land birds in the autumn, when the wind is northwest, illustrating why these birds congregate at the coast line of Connecticut.

The broken circles drawn about a point off the coast of Maine are low-pressure isobars indicating a storm center traveling northeast and causing the northwest winds over the northeastern part of the United States. At the point *A* the hawks follow a narrow path and fly low; at *B* the hawks gradually separate, usually flying higher as the wind becomes more favorable.

southeast until they reach the Atlantic coast line. They then turn westward and follow the shore until they have reached New York and New Jersey, where they gradually separate and pass on southward. Thus the hawks migrating from a large area of country — eastern Canada, New England, and perhaps northeastern New York — are forced to travel along a narrow coastline path at right angles to the main direction of their migration.

A condensed table of flights which occurred from 1885 to 1895 is given below. It has already been published in part, but it is necessary in the present paper for the purpose of showing certain new facts that will be presented.

The meteorological data in the table as formerly given was that for New Haven, Conn., where the observations on hawk flights were made. In the table as given at present the observations of the U. S. Weather Bureau taken at Boston are substituted for those taken at New Haven. This change is made because the former station is nearer the locality where the hawks start on their migratory journey than the latter place. Another column has been added to the table for the purpose of showing the effect of temperature changes on the migratory movements of the hawks. The meteorological data in the tables have been kindly furnished by the Boston office of the U. S. Weather Bureau.

It is difficult to determine the number of hawks that pass a given point on the Connecticut shore, during a moderately large flight in September. An estimate, which appears to the author to be conservative, is that over 15,000 of them pass New Haven in one day. The sharp-shinned hawks outnumber the other species several times over. The broad-winged hawks are next in abundance, then the ospreys and marsh hawks which are about equally numerous.

Observations show that many ospreys and marsh hawks cross to Long Island, but it is evident that the main flight of hawks is along the Connecticut shore.

Since 1894 observations have been continued on flights of hawks in Connecticut in autumn, and in New Jersey in spring, which have resulted in bringing to light additional facts relating to the effect of wind on the migration of birds.

Table I.[1]

LIST OF MIGRATORY FLIGHTS OF HAWKS WHICH HAVE OCCURRED IN SOUTHERN CONNECTICUT DURING THE YEARS 1885–95. METEOROLOGICAL RECORDS, BOSTON, MASS.

Date.	Weather.	Wind Direction.	Wind Velocity; Miles per Hour.	Temperature Change in Past 24 Hours	Remarks.
Sept. 23, '85	Rain	N.W.	14	− 7	Moderate flight; *Falco sparverius* common.
Sept. 18, '86	Clear	N.W.	21	− 8	A great flight of small hawks and various other land birds.
Sept. 22, '86	Partly cloudy	N.W.	10	− 2	*Buteo latissimus* abundant.
Sept. 16, '87	Clear	N.	12	− 5	A great flight all day.
Sept. 17, '87	Clear	N.W.	8	− 7	*Buteo latissimus* abundant early in the morning.
Sept. 24, '87	Clear	N.	14	− 10	*Buteo latissimus* abundant, also *Accipiter velox*.
Oct. 19, '87	Cloudy	N.	10	− 11	No large flight, but almost all the migrant hawks observed.
Sept. 10, '88	Cloudy	W.	9	− 2	*Accipiter velox* abundant.
Sept. 22, '88	Cloudy	N.	24	− 3	Moderate flight.
Sept. 22, '89	Clear	W.	14	− 8	
Sept. 28, '89	Clear	W.	14	− 5	Very large flight.
Oct. 15, '89	Clear	N.	19	+ 5	Moderate flight; *Accipiter velox* plentiful.
Sept. 18, '90	Cloudy	W.	13	− 2	40 hawks killed; *Buteo latissimus* abundant.
Sept. 21, '90	Clear	N.W.	14	− 16	Moderate flight.
Sept. 23, '90	Clear	W.	14	+ 2	*Pandion haliætus carolinensis* abundant.
Sept. 24, '90	Clear	N.W.	20	− 8	Small flight.
Sept. 8, '91	Clear	W.	11	− 2	Hawks increasing in numbers.
Sept. 9, '91	Clear	W.	10	− 5	A large flight; killed over 20 hawks.
Sept. 14, '91	Clear	W.	11	+ 2	Small flight.
Oct. 21, '92	Cloudy	W.	9	− 3	Small flight of *Accipiter velox*.
Sept. 20, '93	Clear	W.	8	+ 1	Large flight; *Buteo latissimus* abundant.
Sept. 21, '93	Clear	N.W.	12	− 12	Great flights of adult *Buteo latissimus*.
Sept. 13, '95	Cloudy	N.	14	− 10	Large flight.
Sept. 14, '95	Clear	N.W.	14	− 11	Great flight of *Buteo latissimus*.

[1] The flights of hawks recorded in the above table were observed at New Haven, Conn., and the meteorological data given is that for Boston, from 1885 to 1887 at 7 A.M., from 1888 to 1895 at 8 A.M. The reason for giving the meteorological conditions for Boston has been already explained.

During September, 1895, daily observations were made on the migration of hawks at New Haven, Conn., when as far as possible the variety, as well as the number of hawks which were seen on each day, was noted. A record was also kept of the meteorological conditions for the same period, particularly the state of the weather and the velocity and direction of the wind.

The observations extended over a period of twenty-three consecutive days, from September 6 to September 29, this being the month during which five or six species of hawks migrate southward. The object of these observations was to ascertain if wind from a southerly quarter not only retarded the migration, but practically stopped it, and also to determine if the migratory movement ceased when there was little or no wind. The observations were as follows:

Sept. 6. Fair; wind N.E., 11 miles. 1 bald eagle; 1 fishhawk; 2 sharp-shinned hawks.

Sept. 7. Fair; wind N.E., 16 miles. 1 broad-winged hawk.

Sept. 8. Cloudy; wind S.W., light. 1 sharp-shinned hawk.

Sept. 9. Cloudy; wind S., light. 1 large hawk; 1 sparrow hawk.

Sept. 10. Warm and hazy; wind S., very light. No hawks seen.

Sept. 11. Cloudy; wind S.W., 10 miles. 1 fishhawk; 1 sparrow hawk; 3 sharp-shinned hawks.

Sept. 12. Fair; wind S.W., light. No hawks seen.

Sept. 13. Clear, cool; wind N.N.W., 22 miles. Several flocks of broad-winged hawks of from ten to fifteen observed; 4 adult bald eagles; hundreds of sharp-shinned hawks, and fish, sparrow, and marsh hawks common.

Sept. 14. Clear, cool; wind N. by W., fresh. All the hawks which were observed yesterday, common to-day. A number of eagles also seen. Broad-winged hawks exceedingly abundant; flock after flock passed westward over New Haven, Conn. Eighty-five were counted in one flock, while another equally large body of them was observed at the same time. These hawks passed over the city continually from 7 A.M. until 3 P.M.

Sept. 15. Clear, cool; wind N., light. A few hawks observed migrating at a high altitude.

Sept. 16. Cloudy; wind N. to S.W., light. No hawks seen.

Sept. 17. Clear; wind S., 5 miles. 2 fishhawks; 1 sharp-shinned hawk.

Sept. 18. Light rain; wind N.E. No hawks seen.

Sept. 19. Light rain; wind S., light. 1 fishhawk.

Sept. 20. Cloudy; wind S.W., light. No hawks seen.

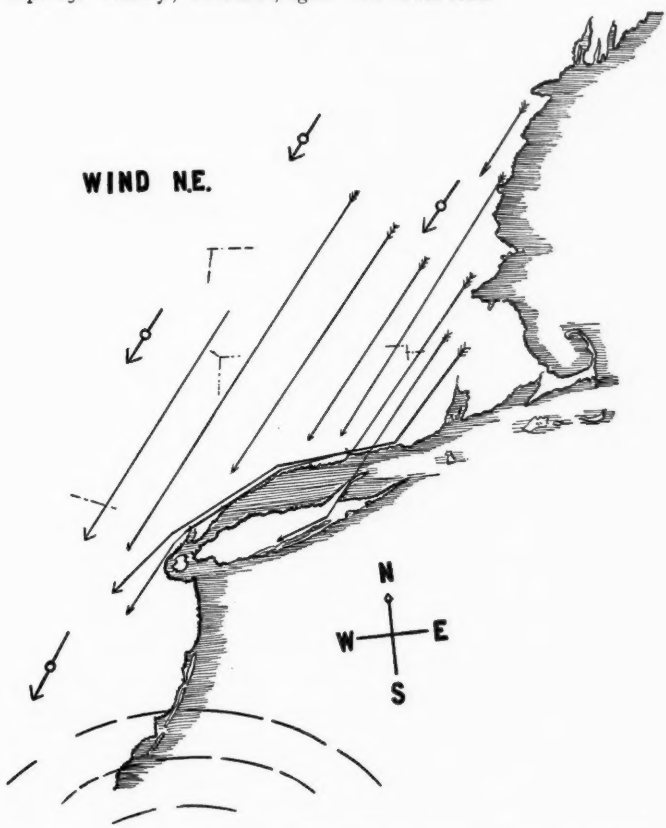
Sept. 21. Clear, warm; wind W. No hawks seen.

Sept. 22. Clear; wind N.W., light. A few sharp-shinned hawks.

Sept. 23. Wind W. by N., light. No hawks seen.

Sept. 24. Cloudy; wind N., 12 miles. A small number of broad-winged and sharp-shinned hawks and one each of the following species: fish, marsh, and sparrow hawks.

Sept. 25. Stormy; wind S.E., light. No hawks seen.



MAP II.—COAST LINE OF THE NEW ENGLAND STATES AND NEW JERSEY.

In this case the long arrows indicate the direction of migration of hawks in the autumn when the wind is northeast. A storm center is indicated by low-pressure isobars south of the New Jersey coast, causing northeast winds in New England. When the wind is northeast there is usually a small flight of hawks along the Connecticut shore, as indicated.

Sept. 26. Fair; wind S.W., 10 miles. 2 fishhawks; 1 sparrow hawk.
Sept. 27. Cloudy; variable light winds. No hawks seen.
Sept. 28. Clear; variable light winds S.E. 1 fishhawk.
Sept. 29. Stormy; wind E. 1 fishhawk.

In the table given below are placed the days, thirteen in number, taken from the above list, when not more than one hawk was seen. The meteorological conditions at New Haven on these days is also recorded in the table. An inspection of the observations shows that no strong northwest winds occurred on any of these days.

TABLE II.

Date, 1895.	Weather.	Wind Direction, Lower Strata.	Wind Velocity, Miles per Hour.	Number of Hawks observed.	Direction of Upper Strata.
Sept. 7	Fair	N.E.	15	1	—
" 8	Cloudy	S.W.	18	1	—
" 10	Fair	Variable	—	0	—
" 12	Fair	S.W.	7	0	—
" 16	Cloudy	S.W.	7	0	—
" 19	Rain	N.E.	6	1	N.E.
" 20	Cloudy	S.W.	5	0	W.
" 21	Clear	W.	2	0	—
" 23	——	W.	1	0	W.
" 25	Cloudy	E.	Light	0	N.
" 27	Cloudy	N.	4	0	—
" 28	Clear	N.	9	1	—
" 29	Cloudy	N.E.	7	1	S. by W.

It has been observed that the direction of the movement of the upper strata does not influence the migratory movement, and that the surface currents are those in which the hawks usually migrate. In the last column of Table II the direction in which the upper strata were moving is given in a few cases. The table, of course, is not meant to show the number of birds migrating, but it gives an idea of the number of hawks observed by one constantly watching for them.

In the table given below, the U. S. Weather Bureau observations are those for Boston on the days given in Table II. It is evident from a comparison of these two tables (II and

III) that the meteorological conditions on nearly all days were very unsettled in New England, and that although in a few cases the wind direction, for a time at least, was favorable for a migration of hawks near Boston, the adverse conditions in Connecticut stopped the migratory movement.

Table III.

UNITED STATES WEATHER BUREAU OBSERVATIONS AT BOSTON, MASS., 8 A.M., SEPTEMBER, 1895.

Date, 1895.	Weather.	Wind Direction.	Wind Velocity, Miles per Hour.	Temperature Change in Past 24 Hours.
Sept. 7	Cloudy.	N.	13	+3
" 8	Cloudy.	N.W.	14	−1
" 10	Cloudy.	N.W.	3	+1
" 12	Cloudy.	N.W.	5	−2
" 16	Cloudy.	S.W.	12	+3
" 19	Cloudy.	N.	8	+4
" 20	Partly cloudy.	W.	12	+6
" 21	Clear.	N.	2	−1
" 23	Clear.	W.	7	+2
" 25	Clear.	N.	3	−2
" 27	Cloudy.	W.	12	−3
" 28	Clear.	N.	7	−10
" 29	Clear.	E.	18	+2

In Table II, as well as in Table III, the directions and velocities of the winds were taken from the local U. S. Weather Bureau records.

There is a slight discrepancy between some of these observations and those taken by the author and given previous to Table II. These differences are due to variations in the direction of the wind on certain days. For example, part of the morning of September 28, Table II, the wind direction was S.E. and light, while at the time of the U. S. Bureau observation it was N., 9 miles. The table on the following page shows the days of September, 1895, when flights of hawks occurred.

TABLE IV.

DATE, 1895.	WEATHER (New Haven).	WIND DIRECTION (N.H.).	WIND VELOCITY (N.H.).	NUMBER OF HAWKS OBSERVED.
Sept. 13	Clear.	N.N.W.	22	Large flight.
" 14[1]	Clear.	N.W. to N.	9	Very large flight.
" 15	Clear.	N.	13	Small flight.
" 24	Cloudy.	N.	12	" "

The observations made of flights of hawks that have occurred during a period of fifteen years show that they have taken place on nearly every date during September, after the 5th of that month. This is readily seen from Table I, which gives the flights of hawks which occurred during the years 1885 to 1895. It is evident that there is no special date on which the hawks migrate during the month of September. Their appearance in large numbers must be due therefore to some special influence. This has already been shown to be the wind from the northwest quarter, in which the birds drift southeastward to the coast line, making necessary their flight along the shore of Connecticut.

The observations made during September, 1895, show an additional fact; if hawks migrated regularly in New England throughout September without regard to the direction of the wind, then there would be a small continual flight of hawks in southern Connecticut during the entire month, due to the peculiar shape of the coast line. Such would be the case, because hawks migrating in a southward direction through the New England States would eventually reach the southern border of Connecticut, where it would be necessary for them to fly westward along the coast, producing the small daily flights referred to.

It has been proved that no daily flight takes place, only a few stray hawks being observed. Moreover, at any time

[1] In Table IV the velocity of the wind at 8 A.M., September 14, is given as 9 miles at New Haven. At Boston, however, at the same time the wind was N.W. 14 miles, and at New York 12 miles.

On September 24 the wind at Boston was N. 18 miles, and at New York N.W. 14 miles.

during the month a flight of many thousands of hawks will occur if the wind turns to the northwest quarter, the hawks appearing within several hours after the change of the wind takes place. This is shown by the following example:

The morning of September 18, 1890, was warm and calm. In the most favorable station for observations near New Haven, between sunrise and nearly eight o'clock, only two hawks were observed. About eight o'clock a breeze started up from the northwest, and a great number of hawks soon appeared, over forty of which were shot. Again, on September 12 and 23, 1895, no hawks were seen, but on the dates immediately following, September 13 and 24 respectively, hawks appeared in large numbers.

The significance of these facts is that the wind not only changes the line of flight of the migrating hawks, but that it is also the immediate cause of their migratory movement.

In further proof of this statement it has been observed that when a northwest wind blows for three days in September, on the third day hawks are not abundant; for all of those hawks which are ready to fly southward start at once when the wind begins to blow in a favorable direction.

A second wind from the northwest quarter, after a week of southerly winds or calm, will produce a second flight of hawks, usually of shorter duration than the first.

A third favorable wind will seldom cause another large September hawk flight, although every wind from the north or northwest throughout the autumn produces a greater or less abundance of hawks along the Connecticut coast.

The expression "the immediate cause of migratory movement," used in the present paper, perhaps requires an explanation: If a favorable wind, acting as a physical agent, is used by birds as a means of migration, it is also an immediate cause of their migratory movement because it determines the time of their migration.

By the expression "favorable wind" is meant a wind which when resolved into components with respect to the migratory direction shows one favorable to the migration.

EFFECT OF TEMPERATURE CHANGES ON THE MIGRATORY MOVEMENTS OF HAWKS.

To what extent these flights of hawks and other land birds are due to changes of temperature is difficult to determine. An examination of the data given in Table I, however, shows the following facts :

1. The direction of the wind at Boston at the 7 and 8 A.M. observations on days when twenty-four flights of hawks occurred was as follows: north, six days; northwest, eight days; west, ten days. Total, twenty-four days.

2. The mean velocity of the wind for the twenty-four days (morning observations) was thirteen miles an hour, maximum twenty-four miles per hour, minimum eight. (In many cases the wind increased considerably during the day.)

3. Mean change of temperature in past twenty-four hours of twenty-four days on which flights occurred was – 5.7 degrees.

4. The number of days with higher temperature than the preceding day was four (+ 5 + 2 + 2 + 1).

5. The number of days with lower temperature than preceding day, but less than three degrees change, was six (– 2 – 2 – 3 – 2 – 2 – 3).

From the above it is seen that on ten days of the twenty-four in the table the temperature was either higher than the preceding day (in four cases) or lower by not more than three degrees. It seems evident, therefore, that the chief causes of the great migratory movements that occurred on the days given in the table were the favorable winds and not diminution of temperature.

TIME OF DAY DURING WHICH HAWKS MIGRATE.

When hawks occur in flights during the autumn migrations they usually make their appearance some time after sunrise and continue flying all day, the maximum of the flight occurring in the forenoon in southeastern Connecticut and in the afternoon near the New York state line. In the former locality the sharp-shinned hawks begin to appear soon after sunrise and

the broad-winged hawks usually not until about eight o'clock, unless there has been a favorable wind the previous day, in which case the flight begins earlier. Many other species of birds, — woodpeckers, thrushes, blackbirds, etc., — apparently acting under the same influence that produces the migration of hawks, namely, the favorable winds, make their appearance before sunrise near the Connecticut shore and are abundant for a few hours only, because they soon fly back into the country to feed. The birds mentioned are known to migrate at night. Most species of hawks, on the contrary, appear to migrate during daylight only. This point is in agreement with observations made by others.

The Migration of the Broad-Winged Hawk.

The behavior of the broad-winged hawks when they are migrating in flocks is peculiar. If, for example, these birds are soaring together in a flock of from twenty-five to fifty, one bird will be seen to separate from the flock, set its wings, and sail away in the migration direction (west in southern Connecticut). Presently another will follow at an interval of a few hundred feet; then another, until finally the entire flock is observed to be sailing with set wings in single file. When the hawks have sailed from a half mile to two miles this way, they collect together and begin to soar again in an area of about one or two acres and continue circling until they have attained a considerable height. The peculiar manœuver is then repeated.

The broad-winged hawk is the only one of the entire family that shows a decided tendency to collect in large flocks during the migration. Red-tailed hawks are sometimes observed in small flocks.

Hawks blown out to Sea.

Strong northwest winds are undoubtedly the cause of many birds being blown out over the Atlantic Ocean and lost during the southward migration. Hawks form no exceptions, for instances like the following are not unfrequently reported:

When the Munson line steamship *Curitiba*, bound for New York, reached lat. 30° N., long. 70° 30′ W., on Oct. 11, 1900, "five ospreys came on board; two of them were shot, one was captured, one alighted on the after-deck boat and then fell into the sea, and the remaining one fell down the funnel. At dusk on the following day two more hawks were captured." These facts were given to the author of this paper by Captain Hoppe of the *Curitiba*.

When the birds were first seen the *Curitiba* was 500 miles from Florida and 400 miles from Cape Hatteras. According to the U. S. Weather Bureau observations taken at 8 A.M. on October 10, at Cape Hatteras, the wind was north, 28 miles per hour, and on October 11, north, 14 miles per hour. At Boston, on October 11, the wind was northwest, 24 miles per hour.

These strong offshore winds were unquestionably the cause of the appearance of the hawks far out at sea. The *Curitiba* also encountered a large number of bats which had evidently blown out to sea by the northwest wind.

Migrating Periods of Various Species of Hawks in Autumn.

In the table on the opposite page the periods when a number of species of hawks migrate southward in the latitude of Connecticut are given.

Widespread Effect of Storms.

It is well known that high north and northwest winds are directly due to centers of low barometric pressure lying to the eastward.

In the northern hemisphere the motions of the lower strata of the atmosphere about centers of low barometric pressure are counter-clockwise. These low areas are known as storm centers, and in the eastern part of the United States they usually travel in a northeasterly direction. A storm of moderate intensity is shown by Map III, which is an approximate representation of the U. S. Weather Bureau map of

TABLE V.

SPECIES.	DATE.	ABUNDANCE.
Fishhawk (*Pandion haliætus carolinensis*)	Sept. 1–Oct. 15	Abundant.
Marsh hawk (*Circus hudsonius*)	Sept. 1–Oct. 10	Very common.
Pigeon hawk (*Falco columbarius*)	Sept. 10–Oct. 10	Regular, but not common.
Sparrow hawk (*Falco sparverius*)	Sept. 10–Oct. 10	Very common.
Sharp-shinned hawk (*Accipiter velox*)	Sept. 5–Oct. 15	Very abundant.
Cooper's hawk (*Accipiter cooperi*)	Sept. 5–Oct. 15	Very common.
Goshawk (*Accipiter atricapillus*)	Oct. 25–Nov. 25	Occasional, sometimes common in November.
Broad-winged hawk (*Buteo latissimus*)	Sept. 10–Oct. 1	Very abundant.
Red-shouldered hawk (*Buteo lineatus*)	Oct., Nov. (?)	Common.
Red-tailed hawk (*Buteo borealis*)	Oct. 20–Dec. 1	Very common.

September 18, 1900. The map shows the extent of country throughout which north or northwest winds prevailed at 8 A.M. on that date. These winds were reported throughout an area of over 800,000 square miles, and their recorded velocity varied from ten to forty miles per hour.

Owing to these winds a large southward flight of birds must have occurred on the given date in eastern Canada and in the eastern part of the United States.

This map is employed to show also the general migration directions of various water birds in the eastern part of the United States. The arrows *AA* show the probable line of flight of many ducks, swans, and shore birds from the interior of Canada to the North Carolina coast. Those marked *C* show the sea flight of many water birds from Labrador, as noted in the Gulf of St. Lawrence region by the author, and those marked *B* indicate the direction of the coast line migration.

The converging arrows *AA* and *C* explain the abundance of water fowl along the coast of North Carolina.

FLIGHTS OF HAWKS IN SPRING.

From the middle of March until the first part of May flights of hawks occur along the Atlantic coast. These flights appear to be greatest over the hills near the New Jersey coast, but occur also at some distance in the interior. Near Paterson there is a hill about 500 feet high, part of the Watchung range, over which large numbers of hawks pass in the spring. On the west slope of this hill many pits and brushwood blinds are made every year, both in the woods and in the open ground, and are occupied during March and April by men and boys who make a practice of killing hawks for New York and New Jersey taxidermists. The author has witnessed several flights of hawks on this hill, which is the first high land back of the coast.

The most favorable wind for a flight is west, or a little south of west. The red-tailed hawks are the first to appear in the spring, and the sharp-shinned and the broad-winged hawks are the last. The periods when some of the hawks may be expected are given below :

Fishhawk, latter part March to May 1.
Marsh hawk, April.
Sharp-shinned hawk, April 10–May 10.
Cooper's hawk, April.
Broad-winged hawk, April 10–May 5.
Red-tailed hawk, March 1–April 10.

Observations described above seem to warrant the following conclusions :

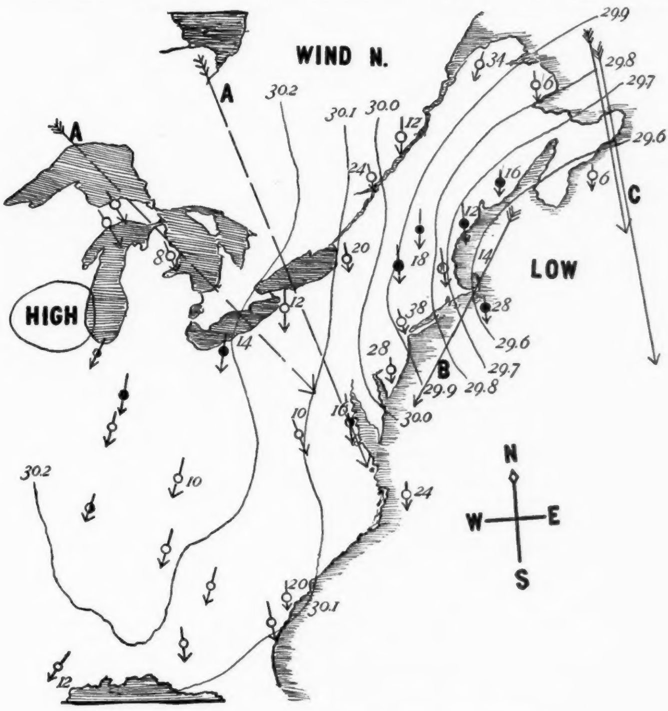
1. That the migratory movements of hawks are largely determined by the direction of the wind, hawks regularly depending on favorable winds as a help in migration.

2. That an adverse wind not only retards the migratory movement, but that it almost completely arrests it.

3. That the migratory period of the various species of hawks lasts for from about fifteen days to one month ; during this time the migratory movements take place on days when favorable winds occur.

4. When the wind is favorable and approximately parallel to the direction of migration, hawks fly and sail at a high altitude and occasionally soar in circles.

5. When the wind is favorable but nearly perpendicular to the migratory direction (the favorable component being small),



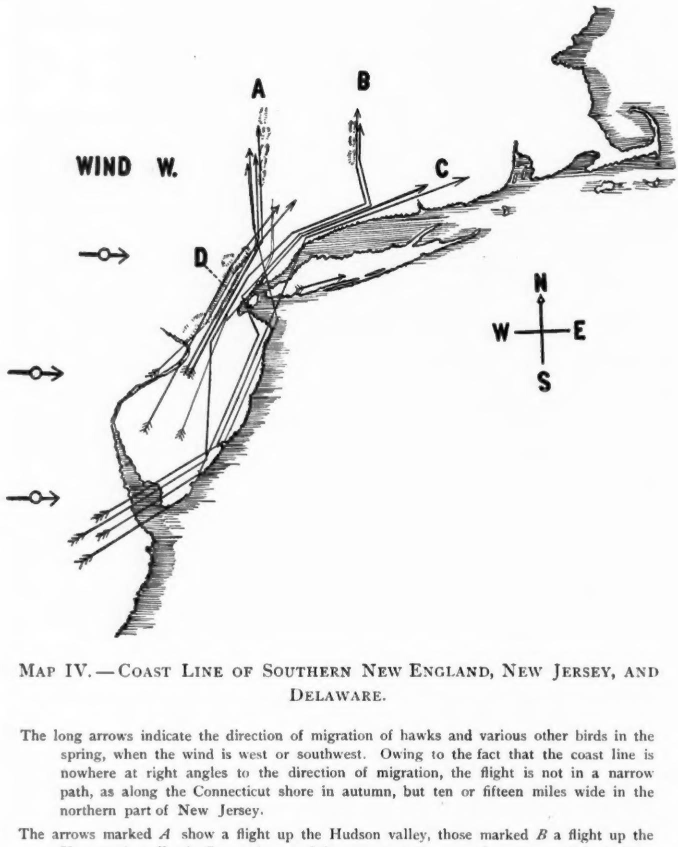
MAP III. — EASTERN CANADA AND EASTERN UNITED STATES.

The dotted lines are the isobars of September 18, 1900. A low barometric pressure is centered off the Maine coast. The small arrows indicate the direction of the wind, and its velocity in miles per hour is given in a number of cases. The mean velocity of the wind records on the map as it is given here is over seventeen miles per hour.

hawks fly low and soar continually, often alternating soaring with the wind and flying or sailing nearly against it.

6. That hawks migrate during the daylight, and, other conditions being the same, they are most abundant in migratory flights when the atmosphere is clear.

7. When a migratory flight of hawks takes place, continued favorable winds exhaust the number of hawks ready to make the migratory journey, but a second favorable wind about one week later may cause a second flight equal in magnitude to the first.



MAP IV. — COAST LINE OF SOUTHERN NEW ENGLAND, NEW JERSEY, AND DELAWARE.

The long arrows indicate the direction of migration of hawks and various other birds in the spring, when the wind is west or southwest. Owing to the fact that the coast line is nowhere at right angles to the direction of migration, the flight is not in a narrow path, as along the Connecticut shore in autumn, but ten or fifteen miles wide in the northern part of New Jersey.

The arrows marked *A* show a flight up the Hudson valley, those marked *B* a flight up the Housatonic valley in Connecticut, and those marked *C* a general northeast flight in New England. The Watchung range, along which many hawks migrate, is indicated by *D*.

8. That a favorable wind, when the favorable component is small, may cause decided deviations of the course of the migrating birds from the main migratory direction.

These conclusions apply to both the northward and southward migrations. Most of the effects of the winds stated are intensified when the wind is strong.

It has been observed that after a period of adverse or light winds, during which no migratory movement was noticed, a moderate wind in a direction favorable to the migration causes a marked migratory movement, especially if such a wind is general and not local. It thus seems evident that birds wait for a favorable wind to carry them on their migrations.

Changes of temperature, without doubt, affect the migratory movements of hawks, but, as has already been shown, a number of large flights have occurred in autumn on days when rises of temperature occurred near where the hawks started on their journeys. Moreover, flights of hawks often occur on cool days in spring, lower temperature usually accompanying west winds at that season of the year.

Water birds, particularly the Limicolæ, migrate in large numbers from the north in July, before the hottest period of the summer has passed. It is not surprising, therefore, to find causes affecting the time of migration of birds other than changes of temperature.

It is probable that many varieties of birds regularly make use of the wind as a physical agent in carrying them on their migratory journeys, the habit being well formed in the case of the Falconidæ.

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New York.

NOTES AND LITERATURE.

ZOÖLOGY.

North American Deer. — *The Deer Family*,[1] by Theodore Roosevelt and others, is a popular account of the deer found in North America, written by men eminently fitted by experience and personal knowledge to deal with the subject from the double viewpoint of the naturalist and sportsman. The first half of the book is by Mr. Roosevelt, who furnishes the introductory chapter (pp. 1–27), and treats of the mule deer, or Rocky Mountain blacktail (pp. 28–64), the whitetail deer (pp. 65–97), the pronghorn antelope (pp. 98–130), and the wapiti, or round-horned elk (pp. 131–164); Mr. Van Dyke writes of the deer and elk of the Pacific coast (pp. 167–191), Mr. Elliot of the caribou (pp. 257–287), and Mr. Stone of the moose (pp. 288–325). Mr. Roosevelt, through his many years of ranch life on the Little Missouri and his numerous protracted hunting trips in the great game regions of the West, writes not only from abundant opportunity for observing the habits of the animals, but with the sympathy and intelligence of a keen naturalist as well as an ardent sportsman.

In the introductory chapter reference is made to the misapplication of names "by all peoples of European descent who have gone into strange lands," not only in reference to some of our deer and pronghorn, but to other game animals and birds. The deer of North America are grossly classified as forming six kinds: "The moose, caribou, wapiti, whitetail, and the two blacktails," minor differences being very properly disregarded. Their geographical ranges and leading characteristics are briefly stated, with some comment on the equipment required by the hunter of large game.

There is reference also to "the most striking and melancholy feature in connection with American big game, — the rapidity with

[1] Roosevelt, Theodore; Van Dyke, T. S.; Elliot, D. G.; and Stone, A. J. *The Deer Family*. New York, The Macmillan Company, 1902. 8vo, ix + 334 pp., 10 illustrations by Rungius, 7 maps by C. Hart Merriam, and numerous half-tone cuts of antlers of moose and caribou. American Sportsman's Library Series, edited by Caspar Whitney.

which it has vanished"; and, says Mr. Roosevelt, "if we are a sensible people, we will make it our business to see that the process of extinction is arrested. At the present moment the great herds of caribou are being butchered as in the past the great herds of bison and wapiti have been butchered. Every believer in manliness, and therefore manly sport, and every lover of nature, every man who appreciates the majesty and beauty of the wilderness and of wild life, should strike hands with the far-sighted men who wish to preserve our material resources, in the effort to keep our forests and our game beasts, game birds, and game fish — indeed, all the living creatures of prairie, and woodland, and seashore — from wanton destruction. . . . But this end can only be achieved by wise laws and by resolute enforcement of the laws."

The work is thoroughly non-technical in character, even to the omission of the scientific names of the species throughout most of the chapters, yet it loses nothing in scientific interest or value thereby. As a contribution to the natural history of the big game of North America its importance cannot easily be overestimated, there being here brought together more first-hand knowledge of the life histories of the species treated than has ever before been placed on record. Mr. Rungius's illustrations are effective and appropriate, while the numerous half-tone cuts of heads and antlers of moose and caribou are important and interesting features. The seven maps, by Dr. Merriam, showing the ranges of the deer, elk, and pronghorn in the year 1900, have a melancholy interest and great permanent value. That showing the present range of the elk is a sad commentary on the wasteful destruction of big game in North America. A hundred years ago this animal ranged from near the Atlantic seaboard westward to the Pacific coast, and from southern Canada into Mexico, forming, in some sections of the country, bands of thousands. Now its range is restricted to a narrow strip of country in the main Rocky Mountains, from Alberta to the northern border of New Mexico, with a few isolated areas of very small extent in California, Oregon, Arizona, Montana, North Dakota, and Minnesota.

The Deer Family is thus not only a book of special interest for the sportsman and the general reader, but an invaluable contribution to the natural history of the deer tribe in North America. It should also stimulate interest in the protection by all rational means of the waning remnants of the former great herds of these noble and attractive creatures.

J. A. A.

Upland Game Birds.[1]— This volume, by Edwyn Sandys and T. S. Van Dyke, is the second in the American Sportsman's Library Series, edited by Caspar Whitney, and, like the first, *The Deer Family*, by Roosevelt and others, shows the editor's good judgment in the selection of his authors for this noteworthy series of books. The scope of the work includes not only the turkey, grouse, partridges, and mourning dove, as would be expected, but also the cranes, woodcock, the upland and golden plovers, and introduced "foreign game," but not the snipe. Although written ostensibly for sportsmen by sportsmen, it has a much broader interest. Its attractive style, varied incident, and personal reminiscences must render it attractive to the general reader, and especially to those interested in the wild things of nature. The successful sportsman is necessarily a keen observer, and long experience in his craft renders him familiar with the ranges and life histories of his favorite objects of pursuit; but few have the literary gift to impart attractively to others the fund of information gained through such varied and extensive opportunities of observation. The authors of the present volume are well equipped for their task, as regards both experience and literary ability.

Mr. Van Dyke's portion of the work (pp. 377–417) relates exclusively to "The Quail and Grouse of the Pacific Coast," with which he shows himself especially familiar. The rest of the field (pp. 1–376) is covered by Mr. Sandys, whose several chapters contain much that is detailed and explicit regarding the habits and peculiarities of the game birds he treats, and in many ways admirably supplement the much that has been written by ornithologists. The spirit of the naturalist pervades the pages of *Upland Game Birds*, although they are amply enlivened by personal reminiscences that should prove especially attractive to the sportsmen; and the authors also neglect no opportunity to castigate the "game hog," and to urge more effective protection for game birds. Five of the nine very effective and pleasing illustrations are by Mr. L. A. Fuertes.

J. A. A.

Nestlings of Forest and Marsh,[2] by Irene Grosvenor Wheelock, contains accounts of the home life of about twenty birds, most of

[1] Sandys, Edwyn, and Van Dyke, T. S. *Upland Game Birds.* New York, The Macmillan Company, 1902. 8vo, ix + 429 pp., frontispiece and 8 full-page plates. American Sportsman's Library Series, edited by Caspar Whitney.

[2] Wheelock, Irene Grosvenor. *Nestlings of Forest and Marsh.* Chicago, A. C. McClurg & Co., 1902. 8vo, xvi + 257 pp., 22 pls., text-figs.

them common and familiar, *e.g.*, the oriole, robin, crow, brown thrasher, a few less well known, such as the long-billed marsh wren and the yellow-headed blackbird. By commendable energy and patience the author has obtained notes describing the selection of the nesting site, the search for materials for building, the care of the young, and their efforts, successful or tragic, to make a start in life. In her "Foreword" the author claims that her book is "as accurate as careful observation in the field can make it"; nor does anything in the book seem inconsistent with this claim. It is not, however, safe to accept all her conclusions from the facts recorded. She says further: "So far as reading human characteristics into animal life is concerned, can any one tell where the brute ends and the human begins? Many of the emotions of man's heart find their counterpart in the life of birds. That we do not perceive this proves only how dull is our sight." The most hazardous attempt to read bird minds is the account, on pp. 119 and 120, of a supposed successful attempt of chickadees to poison a young one which had been made a captive. The story is told in the best faith, but it is an excellent example of what Prof. Lloyd Morgan has felicitously termed "the inability to distinguish the observed fact from the observer's inference." It is curious that the author seems wholly ignorant of Professor Herrick's book, which has laid the foundations of that part of the study of birds which she has chosen for her field. An acquaintance with Professor Herrick's work would have saved her from assuming that a parent bird "seemed to know instinctively which one [of the nestlings] had been fed." The study of the marsh birds is the most interesting part of the book, but several of the other chapters contain bits of valuable information, *e.g.*, the account of the destruction by red-headed woodpeckers of the nests and young of cliff swallows. In an attempt to write brightly and entertainingly, the author too frequently sacrifices dignity, nor can her humor be said to be of a high order. The illustrations are, with a few exceptions, poor, though it should be said that this fact is partly due to the evident reluctance of both the author and the photographer to interfere with the home life of the birds under observation.

A New Genus of Nemerteans.[1] — An important paper by Miss Thompson describes the anatomy, histology, and relationships of a new heteronemertean, of especial interest because it apparently

[1] Thompson, Caroline B. Zygeupolia litoralis, a New Heteronemertean, *Proc. Acad. Nat. Sci. Philadelphia* (December, 1901), pp. 657–739, Pls. XL–XLIV, 1902.

forms a connecting link between two formerly well-differentiated families. The species *Zygeupolia litoralis* is not uncommon at Woods Hole, Mass., and because of its transparency would make an admirable form for class study wherever the living worms can be obtained. Most of the principal features of its anatomy can be demonstrated on the living worm under the low power of the microscope.

The general color of the body appears to be independent of sex and of sexual maturity, while that of the intestinal cæca depends upon the amount and character of the food therein. In external appearance the species so closely resembles *Micrura cæca*, with which it is sometimes associated, in size, shape, and color, "that the two can scarcely be distinguished without a hand lens which reveals the absence of lateral slits in the former and their presence in the latter."

In the excellent and detailed description of the different organ systems the following points are of especial importance: The proboscis has no retractor muscle, its posterior end lying entirely free in the rhynchocœl, exactly as has been described for *Cerebratulus lacteus*.[1] The musculature of the proboscis consists of two principal layers arranged as in many of the Lineidæ, and there are also more or less distinct muscular crosses so characteristic of this family. A strong layer of circular muscles surrounds the posterior end of the stomach, but ends abruptly at the beginning of the intestinal region. This forms a definite inner layer of circular muscles which the author looks upon as homologous with the inner circular layer of Carinella, and which is so highly developed in exactly the same region in Carinoma. Her views are well supported by diagrams and figures, and seem to be conclusive. A similar, but less highly developed, muscular layer has been described for Micrura.

The œsophagus exhibits two well-marked regions differing greatly in histological features, the posterior œsophagal cavity, or stomach, being lined with cells which resemble far more closely those found in the intestine than those of the œsophagus proper. This suggests that the anterior œsophagal cavity only may have arisen from the ectoderm, while both stomach and intestine are derivatives of the entoderm.

The caudal cirrus, or caudicle, has been studied in detail, and the statements of various observers who have described this organ erroneously are corrected. The posterior opening of the intestine lies

[1] Coe. *Trans. Connecticut Acad.*, vol. ix (1895), p. 488.

above the base of the cirrus and not, as has sometimes been described, beneath it. In section the caudal cirrus shows the outer epithelium, a thin circular and comparatively strong longitudinal muscular layer, and a zone of mesenchyme cells surrounding a large central blood space. The two lateral nerves are here situated in the outer epithelium, the outer longitudinal muscular layer and cutis being absent. Neither do the gonads, intestine, nor proboscis sheath continue back into this organ. This description agrees closely with the characters given by Punnett for the caudal cirrus of *Micrella rufra*,[1] except that he finds only rudimentary blood vessels.

The distribution of cutis glands has been very fully studied. A pair of neurochord cells was found in the ventral ganglia. A longitudinal groove on each lateral margin of the body just anterior to the intestinal region is looked upon as a sense organ which may be homologous with the lateral sense organs recently described by Punnett for Micrella,[2] where they are situated just back of the excretory pore, as are the well-known sense organs in Carinella.

Blood lacunæ were not found anterior to the brain; lateral blood vessels are united at intervals below the œsophagus. A large lacuna without definite walls passes into the caudal cirrus. Parasitic gregarines were found in the intestinal epithelium and in the ova. Infected eggs grew to several times their normal size.

The evidence that the genus Zygeupolia should be placed among the Lineidæ seems conclusive, the only feature distinguishing it from other members of the family being the absence of cephalic furrows. It is rightly regarded as the most primitive or aberrant member of that family which has yet been described. With Punnett's new genus Micrella there is certainly a close relationship, and both forms serve to bridge over the gap between the Eupolidæ and the Lineidæ. In many points of anatomy the two genera are very similar, and while in Zygeupolia the cephalic furrows are wanting, yet an approach to this condition is found in Micrella, where the furrows reach only half way to the brain. Punnett's new genus Oxypolia likewise forms a connecting link in the series, although this clearly belongs to the Eupolidæ, being more closely related to Valencinia.

W. R. C.

[1] Punnett. *Quart. Journ. Micr. Sci.*, vol. xliv (1901), p. 553.
[2] Punnett. *Loc. cit.*, p. 551.

BOTANY.

Elementary Plant Physiology.[1] — This new and completely revised edition of the same author's earlier book, *Experimental Plant Physiology*, will without doubt be welcomed by the teacher. The experiments chosen are almost all of the simpler kind, being qualitative rather than quantitative, for which reason they will especially recommend themselves for use in elementary courses.

In the introductory chapter is given a series of selected courses which will serve as useful suggestions to the inexperienced or hurried teacher. At the same time the number of experiments described is sufficiently large to allow of independent choice, so that any course selected from the book may have a certain elasticity — a point of no little importance.

In starting out with the consideration of growth the author has undoubtedly chosen that phase of plant physiology which appeals most strongly to the average student, a fact which warrants the choice, when it is remembered that the object is to introduce the beginner to the subject. The chapters on the exchange of liquids and gases and on the general subject of nutrition are full and seem entirely adequate for the scope of the book. The wisdom of leaving the consideration of the effects of stimulation and correlation (the various trophic phenomena) to the last, in a place removed from the related topic of growth, might be questioned if the evident intention of the author were not taken into consideration. It is clearly his object to impress most strongly upon the student the phenomena connected with general and, on the whole, less complicated problems of plant physiology and to touch lightly upon the more intricate ones connected with correlations of growth. There are many reasons justifying such a treatment in an elementary course, particularly in a course which presumably would not be accompanied by many explanatory lectures or by much reading.

The text is terse and clear, the typography and form of the book excellent, both the author and publisher are to be congratulated on having produced a very acceptable and practically useful laboratory guide.

H. M. R.

Notes. — A new botanical publication, the *Recueil de l'Institut Botanique* (*Université de Bruxelles*), has been launched by Professor

[1] MacDougal, D. T. *Elementary Plant Physiology.* New York, Longmans, Green & Co., 1902. 8vo, xi + 38 pp., 108 figs.

Errera, after the plan of the "Contributions" from various other scientific establishments and laboratories. It is to contain original contributions and reprints of studies from the laboratory that have been published elsewhere. Rather curiously, it begins with Vol. V, but the first four volumes of the series are definitely planned and are promised for the early future. In form and style the *Recueil* is excellent. As would be expected from Professor Errera's own studies, the contents of this volume, as well as of the other four that are promised, are largely physiological or cytological.

Under the title *The New Phytologist*, a new British journal, edited by Professor Tansley, has made its appearance in London. Among other things, the first number contains "A Revision of the Classification of the Green Algae," by Blackman and Tansley.

A new botanical journal, entitled *Magyar Botanikai Lapok* (*Ungarische Botanische Blätter*), is published at Budapest, beginning with January of this year.

The index to new species and varieties published in Engler's *Botanische Jahrbücher*, Vols. XXVI – XXX, occupies 45 double-column pages of the concluding number of the last-named volume.

The April *Bulletin of the Torrey Botanical Club* contains the following papers: Salmon, "Supplementary Notes on the Erysiphaceæ"; Cook, "Development of the Embryo Sac and Embryo of *Castalia odorata* and *Nymphæa advena*"; Piper, "New and Noteworthy Northwestern Plants, VI"; Arthur, "New Species of Uredineæ, II"; and Rydberg, "Studies on the Rocky Mountain Flora, VIII."

The *Ottawa Naturalist* for March contains papers on the botany of the West and Northwest by Macoun and Greene.

No. 2 of the *Biltmore Botanical Studies*, dated April 30, 1902, contains the following papers: Beadle, "New Species of Thorns from the Southeastern States, II"; Boynton, "Studies in the Genus Amorpha"; Boynton, "Two New Southern Species of Coreopsis"; Boynton, "Notes from a Collector's Field Book"; Harbison, "A Sketch of the Sand Mountain Flora"; Harbison, "New or Little-Known Species of Trillium, II"; Beadle, "Studies in Philadelphus"; Beadle, "Two Drupaceous Trees [*Prunus australis* and *P. mitis*] from Alabama."

The January number of the *Bulletin of the Wisconsin Natural History Society* contains the following botanical articles: Brunchen, "Studies in Plant Distribution"; Graenicher, "Flowers adapted

to Flesh-Flies"; Bennett, "Additions to the Flora of Milwaukee County"; and Brown and Fernekes, "Contribution toward a List of Milwaukee County Fungi."

A number of illustrations of botanical interest are contained in the recently published seventh *Report of the Forest, Fish and Game Commission of New York.*

The Engelmann Botanical Club of St. Louis has issued an excellent bulletin on tree planting, giving practical instruction as to what not to do, as well as what to do, in attempting to beautify a city by the growth of trees.

Dr. Urbina, of the *Museo Nacional* of Mexico, has distributed from the *Anales* of that institution a botanical study of the various Zapotes of Mexico.

In a separate recently issued from the *Transactions of the Royal Society of Canada*, Dr. Fletcher writes on the value of nature study in education.

The principles of generic nomenclature are discussed by Mr. Shear in the *Botanical Gazette* for March.

The leaf forms of Liriodendron are discussed and figured by Berry in *Torreya* for March.

An account of the acaulescent violets of central New York, by H. D. House, is published in *Torreya* for May.

A new species of Viola, *V. angellæ*, from New Jersey, is described by Polland in *Torreya* for February.

A yellow-fruited form of *Ilex myrtifolia* is noted by R. M. Harper in *Torreya* for March.

Ailanthus grandis, a new Indian species, is described and figured by Prain in *The Indian Forester* for April; he also gives comparative notes on the other species of the genus and their distribution.

The morphology and anatomy of *Azorella Selago* are treated by Charlotte Ternetz in Heft 1 of Abtheilung I of the *Botanische Zeitung* for this year.

Continuing his studies of Ochnaceæ, Van Tieghem, in the April *Journal de Botanique*, separates from the old genus Ochna the new genera Ochne a, Porochna, and Discladium, giving differential keys for the genera of the tribe Ochneæ as so constituted.

A new Zauschneria, *Z. arizonica*, is described by Dr. Davidson in the *Bulletin of the Southern California Academy of Sciences* for January,—the initial number of this publication.

Dr. Weber, who in former years studied Opuntias with Engelmann, has issued separates, from the *Bulletin de la Société Nationale d'Acclimatation de France*, of an article on the species (*O. leucotricha*) which furnishes the prized "Duraznillo," or peach prickly pear of the high table-lands of Mexico, and its immediate relatives.

An interesting account of the hallucinations caused by taking an infusion of *Anhalonium lewinii* is published by Havelock Ellis in the *Popular Science Monthly* for May.

A photogram of *Echinocactus texensis* is published in the *Monatsschrift für Kakteenkunde* for April 15.

In No. 7 of the current volume of botanical *Proceedings of the California Academy of Sciences*, Miss Eastwood gives a key to fifty-seven species and varieties of Ribes recognized as occurring on the Pacific coast, and describes nine species as new.

Matsumura publishes a list of the wild and cultivated Leguminosæ of Japan, Loochoo, and Formosa, in the Tokyo *Botanical Magazine* of March 20.

M. Theuriet, an amateur of roses, published an illustrated classified list of the 6781 species and varieties cultivated at l'Haÿ, France.

Blanchard has a note on the Vermont chokeberries in *Rhodora* for March.

In *Pharmaceutical Archives* for April, Mr. Denniston publishes a paper on the general and bark characters of *Viburnum ellipticum*.

A large and fully illustrated paper on the comparative embryology of the Rubiaceæ, by F. E. Lloyd, constitutes Vol. VIII, No. 1, of the *Memoirs of the Torrey Botanical Club*.

An account of *Primula parryi*, with an excellent half-tone illustration, is published by Knowlton in *The Plant World* for February.

Scrophularia glabrata, from Arizona, is described and figured by Davidson in the March *Bulletin of the Southern California Academy of Sciences*.

The seeding of *Plantago fastigiata* is the subject of a paper by Griffiths in the *Bulletin of the Torrey Club* for March.

Peperomia davisii, from St. Kitts, is described by Britton in *Torreya* for March.

A cockscomb fasciation of the pineapple is noted by Harshberger in the concluding part for 1901 of the *Proceedings of the Academy of Natural Sciences of Philadelphia*.

In the *Botanical Gazette* for April, DONNELLIA C. B. Clarke is proposed for the reception of *Callisia grandiflora* Donnell Smith. The new genus constitutes one of the many segregates of Tradescantia.

An interesting account of the harvesting, curing, and cleaning of the seed of *Poa pratensis*, the standard lawn grass of the United States, forms *Bulletin No. 19* of the Bureau of Plant Industry of the Department of Agriculture, by Pieters and Brown.

E. D. Merrill publishes some notes on Sporobolus in *Rhodora* for March.

A study of the Zamias of Florida, by Wieland, is published in *The American Journal of Science* for May.

The North American genera of Aspidieæ are discussed by Underwood in the *Bulletin of the Torrey Botanical Club* for March. A key is given to the genera.

The evergreen ferns of New England are considered by Davenport in *Rhodora* for March.

In *The Fern Bulletin* for April Mr. Maxon proposes the restoration of Liebman's name *Asplenium resiliens* for what is commonly known as *A. parvulum.*

In an article on "The Logfern" (*Dryopteris Cristata Clintoniana*), Mr. William Palmer gives a key to the cristata and Goldieana groups of that genus, in *The Fern Bulletin* for April.

The mechanical expulsion of the brood bodies of several species of Lycopodium is noted by Lloyd in *Torreya* for February.

Several species of Lycopodium, and the propulsion of the gemmæ of some species, are considered by Mr. Leavitt in *Rhodora* for March.

The tenth of Mr. Alvah Eaton's papers on the genus Equisetum in North America, in *The Fern Bulletin* for April, deals with the varieties of *E. litorale.*

A monograph of the Lejeuneæ of the United States and Canada, by Evans, constitutes Vol. VIII, No. 2, of the *Memoirs of the Torrey Botanical Club.*

Two new western mosses are described and figured by R. S. Williams in the February *Bulletin of the Torrey Club.*

PETROGRAPHY.

Weinschenk's "Die Gesteinsbildenden Mineralien"[1] affords the most satisfactory introduction to petrography that has yet appeared. Its first 47 pages are devoted to the physical and chemical methods employed in the separation of rock constituents and in the determination of the character of isolated mineral particles. The remainder of the volume describes briefly the principal rock-forming minerals as they appear under the microscope. In spite of the brevity of the treatment necessitated by the small size of the book nearly all the essential facts relating to the characteristics of the individual minerals are to be found in its pages. The reader is supposed to be already acquainted with the general principles of optics, so no space is devoted to this subject.

The special feature of the book is the collection of 18 plates, bound in two brochures and enclosed in a pocket from which they may be removed for ready reference. They contain summaries of the physical, chemical, optical and crystallographic characters of the minerals discussed in the text ; a list of minerals classified according to their color, in thin sections, and their crystallographic habits ; lists of those exhibiting optical anomalies, twinning structures, distinct cleavages, and of those whose powder reacts alkaline ; and lists in which the minerals are arranged according to their magnetic strength, their solubilities, their fusibility, their density, their refracting indices, the strength of their double refraction, and their optical character. These tables are so well arranged and they embody such a mass of information in small compass that they will prove not only useful to younger students but also extremely valuable to those of maturer experience.

So far as the writer knows, the present volume is the only modern elementary treatise on the microscopical characters of rock-forming minerals that can safely be recommended to beginners in the study.

W. S. B.

[1] Weinschenk, Ernst. *Die Gesteinsbildenden Mineralien.* Freiburg, Herdersche Verlagshandlung, 1901. 146 pp., 100 figs., 18 tables.

(*No. 428 was mailed August 19.*)